

Integrated Unmanned Air-Ground Robotics System

FINAL REPORT – VOLUME IV

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Executive Summary

Abstract

Advancements in technology have provided weapons that are smarter and far more deadly than ever before. In an attempt to preserve the lives of troops on the battlefield there exists the need for an unmanned vehicle which is capable of reconnaissance and data acquisition objectives and that can also transport small payloads into and out of enemy territory. In order to fulfill these needs, a compact and lightweight vehicle will be designed with reliability and survivability as the major focus. This paper proposes three systems and a baseline design, which have been considered as possible solutions for the problem. The first two systems are rotary aircraft types, which are based on current technology and design ideas. The second system is a hovercraft, which utilizes ducted fans for hover mode and rotate to produce forward flight. The third system is based on an innovative technology involving ionic propulsion. This system is based on current “Ionic Breeze” technology and produces a near quiet acoustic signature and no thermal signature. With future research and development it is possible that this technology will be adequate for use by the proposed roll out date.

Resumé

Les avancées technologiques de ces dernières années ont vu apparaître des systèmes d’armes de plus en plus sophistiqués et destructeurs. Dans un souci de préserver les vies des soldats sur les champs de bataille, le développement de drones apparaît comme la solution idéale. Ces systèmes étant capables de missions de reconnaissance et de collectes d’informations stratégiques de manière autonome, tout en transportant une certaine quantité de charge utile en terrain ennemi.

Pour répondre à ces besoins, un drone léger et compact doit être développé en insistant sur les critères de fiabilité et de furtivité.

Ce document propose trois concepts répondant aux critères précédents en plus d’un concept de référence:

- Le premier reprenant les principes de l’hélicoptère est basé sur des solutions technologiques actuelles, ceci dans un souci de facilité de développement et de réduction des coûts.
- Le deuxième concept reprend la technologie des aéroglisseurs, en utilisant des rotors carénés pivotants pour produire la poussée verticale et horizontale. Quoique plus innovant, ce concept reste basé sur des technologies éprouvées.
- Le troisième concept plus avant-gardiste, repose sur des technologies naissantes telle que la propulsion ionique et qui verront leur maturité dans les années à venir.

Ce drone est basé sur un système de propulsion original baptisé « souffle ionique » qui offre l’avantage d’une discrétion absolue en terme de signature acoustique et thermique.

Ce sont les prochains développements en matière de propulsion et de sources d’énergie qui rendront possible l’utilisation de ces nouvelles technologies pour une échéance à 10 ans d’un tel concept.

UAGV Compliance List [Optional]

The following list details the location of all specification compliances for the UAGV. The list shows the location in the CDD provided by the Army of every specification and the number of the page where that specification is dealt with in this proposal. **[The following list is an example.]**

Specification:	CDD location:	Proposal location:
Must be capable for use in terrain definition	1.1.3	2.6
Capable of both autonomous and semiautonomous operation	1.1.5	2.6
Capable of human interface as required	1.1.5.1.....	2.2
Capable of executing both a preplanned and an alter mission profile	1.1.6	2.2
Capable of gathering information on threat activities at range	1.2.2.1	2.6
Capable of carrying a payload of 60 lbs gross weight	1.2.3.1	1.4
Capable of having a minimum cruise speed of 30 km/hr	1.2.3.2.1.....	2.3
Capable of landing in an unprepared area	1.2.4.1.1.....	2.8
Capable of avoiding sonic detection	1.2.4.3.1.....	2.3
Capable of a 250 fpm VROC	1.2.4.3.4.....	2.3
Capable of a flight profile of hover to full flight	1.2.4.4	2.3
Capable of operation under battlefield obscurants	2.2.4	2.2
Shall contain robust and have secure modes Of operation for communications	2.3.3.1	2.7
Shall be simultaneously LOS and BLOS	2.3.3.2	2.7

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Common Terms and Acronyms List

Word	Comments
AGL	Above Ground Level
AGL	Above Ground Level
AIAA	American Institute of Aeronautics and Astronautics
AMCOM	United States Army Aviation and Missile Command
BLOS	Beyond Line of Sight
CAD	Computer aided design
CDD	Concept Description Document
CM	Communication
Concept Description Document	Document that details the customer's technical specifications for the UA/UGV
CST	Central Standard Time
Customer	John Fulda and Jim Winkeler
Dry Weight	
EE	Electrical Engineering
EH	English
EM	Engineering Management
EST	Editorial Support Team
ESTACA	Ecole Superieure des Techniques Aeronautiques et de Construction
FLOT	Forward Line of Troops
Ft	feet
GRAD Inc	Global Research and Development (Team 3)
IPT	Integrated Product Team
IRP	Intermediate Power Rating
JAUGS	TBD
JCDL	TBD
Joint Vision 2020	TBD
Km	Kilometer
lbs.	pounds
MAE	Mechanical and Aerospace Engineering
MKT	Marketing
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
Nm	Nautical miles (~2025 yds.)
Payload	Item carried by the system having a specified weight
PEM	Proton Exchange Membrane
Phase I	Baseline review, conducted on conventional configuration using current and experimental technology, assess technologies clarify the Concept Description Document
Phase II	Alternative concepts review, development and evaluation of four prototype designs to meet customer specifications. Select a preferred design.
Phase III	Final Evaluation, detailed design specifications of

RFP	selected design concept
RMA	Request for Proposal
Style Guide	Revolution of Military Affairs
	Document that specifies the mechanics of writing documents required for the project
TBD	To be determined (not know at this time)
TBE	Teledyne Brown Engineering
TF/TA	Terrain following/terrain avoidance
UAH	The University of Alabama in Huntsville
UAV	Unmanned Air Vehicle
UAGV	Unmanned Air/Ground Vehicle
UGV	Unmanned Ground Vehicle
U.S.	United States
VROC	Vertical rate of climb
VTOL	Vertical takeoff and landing

Team-Specific Terms and Acronyms List

Word or symbol	Comments
<i>AFCS</i>	Aircraft Flight Control System
<i>BTU</i>	British Thermal Unit
C_D	Drag Coefficient
D	Vehicle Drag
<i>GPS</i>	Global Positioning System
<i>HP</i>	Horse Power
<i>JP-8</i>	Jet Fuel
kW	Kilowatt
kWh	Kilowatt-hour
<i>Mbps</i>	MegaBits Per Second
<i>Theater of Operations</i>	Area of conflict
V	Vehicle Air Speed
<i>PEM</i>	Proton Exchange Membrane
<i>UWB</i>	Ultra Wide Band

IPT 3: Feasibility of Unmanned Air/ Ground Vehicle (UAGV)

1.0 UAGV – Unmanned Air/ Ground Vehicle

1.1 The Need

In an evermore demanding and dangerous battlefield there is an increased need to have a complete understanding of the entire theater of operations. It is in this theater of operations that front line troops risk life and limb to provide a real time assessment of enemy movements and positions to aid in strategic battlefield planning. Even with first hand situation reports it is difficult to compile a complete and totally accurate portrait of the entire theater of operation. The daunting task of creating this portrait has become increasingly easier due to technological advances, such as the advent of satellite surveillance and wireless communication. However advanced, these technologies are limited by range, and lack vision and accuracy. Technological leaps on the horizon will enable our forces to manipulate tomorrow's battlefield like a well-played chess game.

Dominance in the future battlefield will require troops to perform dirty, dangerous, and dull operations close, if not beyond, the line of fire. An increasing dependence is being placed on machines to perform these operations previously performed by military and other uniformed personnel. On the battlefield, the combined use of air and ground units provide the best overall view of the situation enabling personnel to make the most equitable decisions. Using machines on the front lines as scouting units has greatly reduced the risk to human personnel, however these machines are bulky, noisy, and require a great deal of direction during the mission. Merging technologies to create one vehicle that incorporates both air and ground capabilities that will be the dominant reconnoitering unit on the future battlefield is the vision of the U.S. Advanced Systems Directorate (AMCOM).

1.2 The Requirements (Nathan Smith)

The Unmanned Air/Ground Vehicle (UAGV) sought by the U.S. Advanced Systems Directorate (AMCOM) is envisioned to provide essential scouting and target recognition to the Brigade Commander. The customer and all participating teams endorsed a Concept Description Document (CDD) finalizing the customer requirements for this system on February 6, 2001. Phase 1 of the project produced one baseline concept that attempted to satisfy the project (CDD) using existing technology.

1.3 The Solution (Kodrowski)

The Ionic Defender has been created to meet all of the requirements set forth in the specifications from AMCOM. Ionic Defender will get you there, will let you know what is out there, and will return safely faster, cheaper, and with higher performance than its competitors. This UAGV uses a completely silent ionic propulsion system that is powered by the next generation of fuel cells. It incorporates the use of an exoskeleton framework structure for a reduction in weight as well as for improved survivability. Sensors are imbedded into the skin to minimize housing components. The skin itself is comprised of layers of radar reducing material alongside high strength materials. The UAGV has good ground mobility and excellent communication with home base. Uniquely setting itself apart from its competitors the Ionic Defender has a top down thinking process utilizing the best compilation of information gathering available. It's obvious. The Patrocinor delivers. Yes, it

challenges its design team to package this cutting-edge vehicle for reliability but the system uses technology that is already out there in some form thereby minimizing overall costs for development.

Money is a good place to start in describing the key features of the Patrocinor. For an estimated cost of 170 mil\$ in today's U.S. dollars the U.S. Army can have all of their needed capability by the year 2020. It's not the cheapest on the market but it is far from the most expensive. What AMCOM gets for its money is a vehicle that will change the face of warfare forever. Our soldiers will be protected well behind the front line while a swarm of Ionic Defenders communicate vital information about the enemy in real time back to home base. This comes at a fraction of the cost of some of the military's other high-tech ventures.

The Patrocinor brings to life ionic propulsion. This unique propulsion system has never been used in a military application before, but this system has no moving parts, no emissions, and minimal power requirements. Screens are used to charge air particles in the ducts and accelerate them out the back of the vehicle, in turn propelling the Ionic Defender quietly and effectively to its destination.

Fuel cells are the propulsion method of choice for the Ionic Defender. The decision to use fuel cells came about from the power to weight ratios that burdened the baseline design. Ultimately, fuel cells are being heavily researched at this time both by the military and commercial venues and they offer the best power in the smallest sizes and the cheapest costs.

Top down thinking is the only way to go. It is a feature that doesn't increase costs or complication. It is a methodology that raises reliability immeasurably and lends itself to the thought processes of the military operators who will be handling the Patrocinor. This thought process is unique to the Patrocinor, and developed solely by GRAD Inc. for the purpose of this unmanned vehicle. The processes are based on requirements set forth in the specification. The advantages that Patrocinor brings to the table continue with the choice of materials for fabrication, aerodynamic design, and ground mobility.

1.3.1 Concept Overview (Jason Back)

The Ionic Defender is designed with the purpose of maintaining a low radar cross section and near quiet acoustic signature. In order to produce a near quiet acoustic signature, a virtually silent propulsion system is used. This propulsion system is based on Electro-kinetic air transportation technology. This transportation system will be used for both vertical, horizontal and "near earth" flight configurations.

The Ionic Defender utilizes ion propulsion for vertical and horizontal flight. Ion propulsion uses high voltage electric plates to ionize the surrounding air. The ionized air is then attracted to another grid and ducted out. The electricity is provided by high capacity fuel cells. This process is completely silent and creates no heat. The ion engines will be used for hover for near ground activities and for VTOL. Also there will be separate ion engines for horizontal propulsion. The lifting body design will reduce the need for the vertical ion engines during horizontal flight.

The power source for this system is a Proton Exchange Membrane (PEM) fuel cell. PEM fuel cells operate at low temperatures with excellent efficiencies. The fuel cell will be supplied with fuel processed from an external reformer.

The flight control and navigation systems are fully autonomous. The flight control and navigation system is based on a top-down process with input from several sensors and cameras. The vehicle is able to direct itself depending on its mission profile. There will be backup systems and redundant systems in case of any failure in any part of the sensor package. Communication for this concept will implement ultra wide-band technology for LOS and BLOS communications. These communications can be sent from the ground station or current military satellites.

The monocoque structure of this concept gives the concept tremendous strength and durability. The monocoque uses an exoskeleton design with a layered composite skin. The skin is layered with carbon fiber, bore fiber, electro-chrome, and radar absorbing material. The fiber structure is the strongest part of the skeleton. The electro-chrome layer absorbs electromagnetic radiation emitted from within the vehicle and outside the vehicle. Lastly the skin is covered with a radar-absorbing layer to lower the radar cross section adding to the vehicles stealth capabilities.

Since the specification does not require that the vehicle actually move on the ground, wheels, legs, tracks, and other methods of ground mobility can be dropped from consideration. A simple solution is to utilize a system that is similar to most retractable landing gear systems used today. A landing strut will be housed within the skin of the vehicle and a push-pull pneumatic cylinder used to extend and retract the strut.

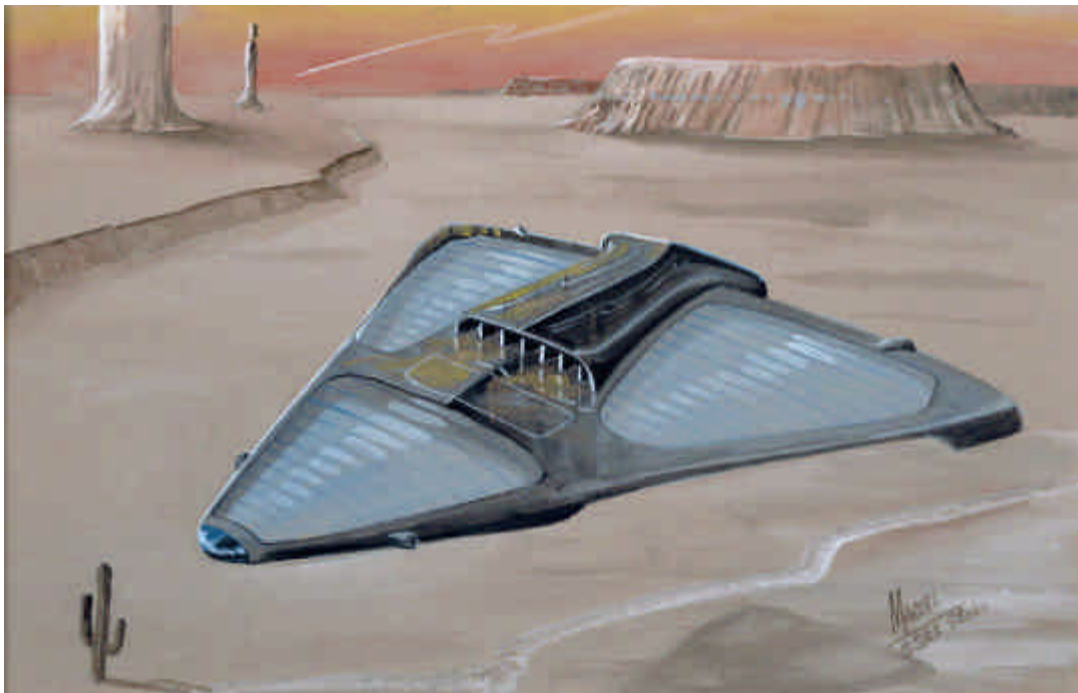


Figure 1. Artist Drawing

1.3.2 Dimensional Properties

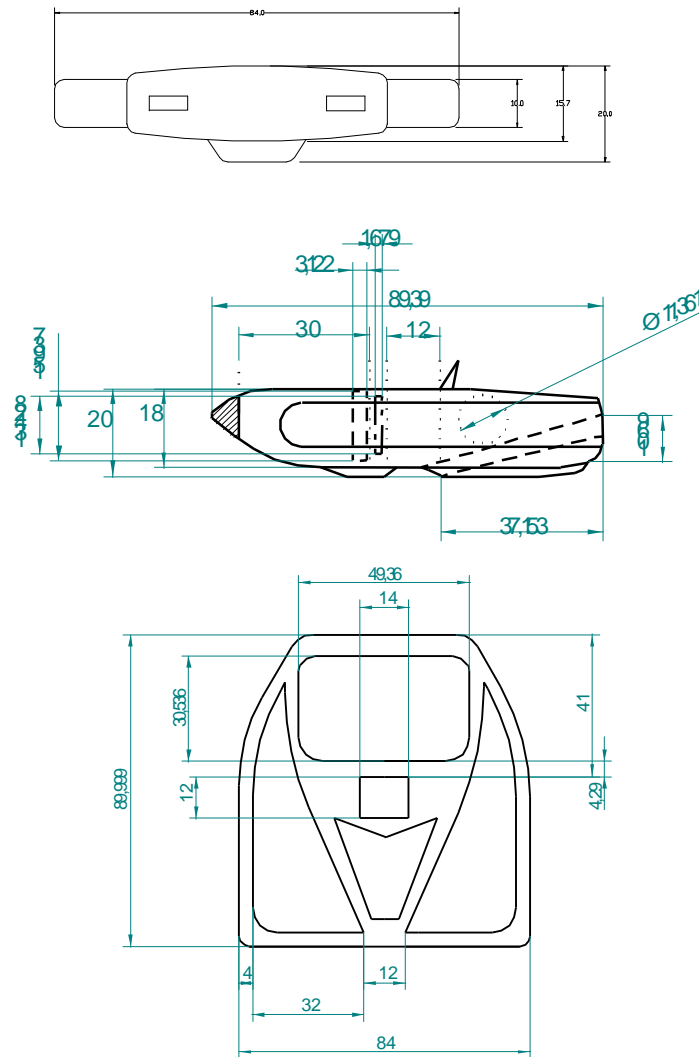


Figure 2. Three-View Drawing

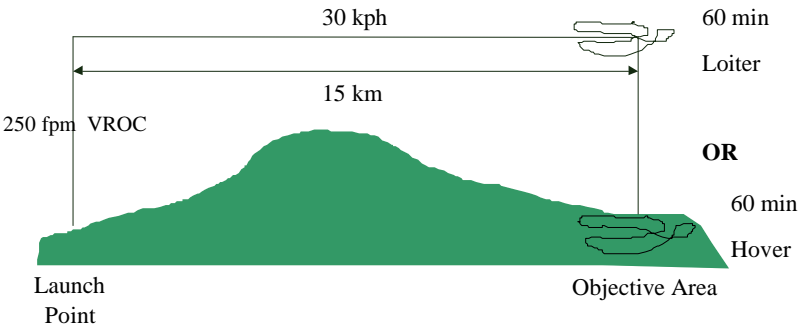
1.3.3 Operations Scenario

The customer requirements for the system were endorsed on February 6, 2000. These requirements make no mention of a mission profile for the UAGV pertaining to its capabilities or objectives. Therefore, a mission profile for the vehicle was assumed based on the minimal criterion set forth in the customer specification.

The operational scenario for the Ionic Defender is based on customer requirements and mission profile assumptions. The vehicle will be launched from the ground, with a vertical rate of climb of 250 feet per minute. It will then proceed a distance of 15 kilometers

at a speed of 30 kilometers per hour. The Ionic Defender will have the capability to hover in the air or low to the ground for approximately 60 minutes and land safely if need be. The vehicle can then return back to its point of departure in approximately 30 minutes.

Figure 3. Operations Scenario



1.4 The Performance (Jason Back)

The Ionic Defender meets all requirements of the CDD. In most areas the vehicle exceeds these requirements. Through preliminary calculations the Ionic Defender is capable of the specified range. The cruise speed and VROC can be attained also utilizing the ionic engines. The vehicle can carry a payload of 60 pounds. Using a top-down thinking process the Ionic Defender will be fully autonomous. New technology developed for communications and sensors allow the vehicle BLOS and IFF systems. The ionic engine is completely silent, giving the vehicle stealth-like characteristics. A deployment of 2025 is reasonable given an adequate investment of research and development of the ionic propulsion system.

Table 1: Final Concept Evaluation

CDD Requirement	Requirement	Assessment	Remark
Range from launch point	15 km	30 km	
Cruise Speed	30 km/hr	60 km/hr	
VROC	250 ft/min	250 ft/min	
VTOL Capability	Yes	Yes	
Payload:	60 lbs	60 lbs	
Operational Altitude	0 to 500 ft AGL	Unlimited	
Hover to full flight profile	Yes	Yes	
Operation	Autonomous or Semi-autonomous	Autonomous	
Acoustic Signature	Near Quiet	Silent	

Communications	BLOS	BLOS	
Deployment	2025	2025	
Other CDD Requirement	IFF	IFF	
Other CDD Requirement			

1.5 The Implementation (Nathan Smith)

The production of this vehicle hinges on the continued development of three key technologies. Fuel cell technology has grown by leaps and bounds soon to be powering automobiles running over 100 miles per hour with efficiencies greater than 80 miles per gallon. This technology has become an investment in the world's environmental future by companies across the globe. Historically, communication has been the factor limiting range, security, and speed of operations. Implementation of ultra wide band communication will provide increased range and ultimate security over high-speed connections. The most infant technology, and perhaps the most innovative, is the ionic propulsion drive technology. This technology will require larger research and developments cost, however this propulsion system provides a unique and virtually quiet alternative to traditional propulsion systems.

In order to achieve an operational system the above outlined technologies need to be developed to maturity. The fundamental technology is the ionic propulsion drive, as there has been little to no research performed in this area since 1958. This is the key to the virtually silent scout vehicle. Key technologies already being funded need to be brought to fruition to provide support and stability to the implementation of this UAGV.

Deployment of this system will depend on the initiation of support programs and the advancement of the technologies outlined above.

This system will fulfill the need of the Army and provide AMCOM with a versatile platform for an array of applications both military and civilian. This platform would take the place of troops performing dirty, dangerous, and dull missions.

2.0 Technical Description of Methods Used [Heading Required] (James Kodrowski)

This section will demonstrate your **technical credibility**. In it you should present detail of your component and subsystem designs with appropriate references to material that you have found. I expect to see paragraphs describing the material, charts, tables, and graphs where appropriate. No table or figure should be presented without mentioning it in the text. You may determine the headings of the subsections marked "Team Specific". The Review Team will be looking at the following items: determination of critical problems, completeness of evaluation, well balanced analysis of complete system, assumptions clearly and logically stated, validity of reasoning, correctness of theory, relation to CDD problems, and relevance of sketches, diagrams and tables.

2.1 Design Initiative: (Nathan Smith)

GRAD Inc. set forth with the philosophy to produce the best solution to the requirements set forth by the U.S. Advanced Systems Directorate. This included merging innovative technologies in unconventional ways. The concept was developed with the highest level of detail in mind.

2.2 System Integration: (James Kodrowski)

The Patrocinor is controlled on the battlefield by a command center located in the rear of the HUMVEE that pulls the Patrocinor. The unit is programmed and launched from the trailer and operated either remotely or autonomously. The unit is capable of following preplanned missions or changing mission profiles in mid flight. This is done either by the onboard controls or the control system at the launch point. The system is capable of recognizance at a distance 30 km from the launch point and able to reach the objective area in less than 15 min. The data from on sight is transmitted via secure wide band communication already being developed by the military.

2.3 Propulsion: (Jason Back)

The concept of ionizing air to produce a flow has existed since the 1950's. This technology derived from electro-static air cleaners. A high voltage potential is placed across two grids; the voltage potential ionizes the surrounding air and causes it to flow through the grids. The second grid is the collecting grid; the grid attracts solid particles to it. The system easily removes a significant amount airborne microscopic debris, thus providing cleaner air. Alexander P. de Seversky patented an electro-static system for propulsion in 1964. Seversky created a large, lightweight structure applying the above technology. He proved that enough lifting force could be produced to sustain flight of a heavier than air vehicle. (USPO 1964)

GRAD Inc. chose ionic propulsion because of its quiet operation and low power consumption. The electro-static system produces no sounds except for the flowing air. This quality provides the vehicle with a lower chance of detection by enemy due to noise. In an article written about Seversky's invention the author claimed, "It sat there silently in midair." (Fantel, 1964) Also, the system requires relatively low power use. This system when compared to a conventional rotorcraft design uses half the power to provide the same lift. Another benefit of the system is that it is less susceptible to damage from projectiles than a turbine or ducted fan. If a bullet is shot through the grids only a few wires may be damaged, but the remaining wires can still operate the vehicle.

The ionic propulsion system consists of a high voltage pulse generator connected to two grids or arrays of wires. A short distance of about four to six inches separates the grids. The top array has an emitting area approximately twenty times smaller than the receiving array. The voltage generator sends a varying positive charge to the top grid, while the bottom grid receives an equal negative charge. This voltage potential ranges from 50kV to 150kV. The surrounding air is ionized and pushed through the duct encircling the arrays. The force exiting the engines is adjusted by varying the voltage potential across the grids; the higher voltage produces more thrust. This allows the vehicle to lift from the ground, to a hover profile, and to a full flight profile. The source for horizontal thrust will be a smaller version of the engine mounted vertically. This engine will duct the airflow similar to a turbojet engine to add additional power.

Preliminary calculations have determined that the power required for the ionic engines is only 25kW. This is powerful enough to allow a VROC of 250 feet per minute. The horizontal engine will give a speed of 50 kilometers per hour.

Although this technology is not widely known, the ionic propulsion system is an easily constructed system. There is little maintenance needed; the system does not have any moving parts to wear out or breakdown. With little investment in development of the engines, there is the possibility of revolutionizing the propulsion industry.

2.4 Aerodynamics: (Kanna)

“The Patriconor” in our specification doesn’t have wings. This follows from the fact that the lift is created not by the lifting wing body, but charged ionizing electrostatic plates arranged in array perpendicular to horizon. Like any shape in the flow creates a drag, the plates also will create drag and resistance to flux of the air mass through the engine. This can significantly reduce the theoretical down wash velocity, hence total lift force. Therefore the shape of the electrostatic grid plates is significant.

This design employs symmetrical NACA 0025 airfoil for grid section with drag coefficient $C_d=0.0143$. The following summary shows the engine drag analyses for front engine.

Table 2. Summary of Calculations

Static plate Airfoil	NACA 0025
Longitudinal plate span	36”
Number of longitudinal plates	9
Lateral plate span	54”
Number of lateral plates	6
Plates spacing	6”
Plate cord	3”
Airfoil section C_d	0.0143
Total grid area	13.5 ft ²
Flow Velocity (down wash)	54.2 ft/s
Drag created in front engine	0.66 lb. or 2.94 N

2.5 Power Generation:

Power for the Patrocinator will be provided by a 25kW Proton Exchange Membrane (PEM) fuel cell. This fuel cell was chosen for its low operating temperature, high power density, and advanced stage of technical development. Because of the rapid increase of technology for fuel cells, the weight is predicted to decrease and the power increase at an approximate rate of 30 percent in four-year increments. (Little 2000) The fuel consumption of the PEM fuel cell is also predicted to improve greatly. At present a 25kW fuel cell weighs approximately 158 pounds and consumes fuel at a rate of 0.201 liters per/minute. (Micro Chemical and Thermal Systems 2000). By using the study “Cost Analysis for Fuel Cell-System for Transportation” by Arthur D. Little, an estimation of a 25kW fuel cell will weigh approximately 55 pounds and consume fuel at a rate of 0.146 liters per minute. As shown in the Power Generations Calculations in section E of the appendix, this specific fuel consumption, based on a fuel density of 800kg/m³ (Hill and Peterson 1932 pg. 242), for

aviation kerosene will require approximately 10 gallons of fuel with an approximate weight of 46 pounds.

2.5.1 Fuel Cell Components:

A typical PEM fuel cell system is comprised of a fuel reformer, fuel cell stack, and a power conditioner. Each of these components plays a vital role in converting fuel to electrical power with very low emissions.

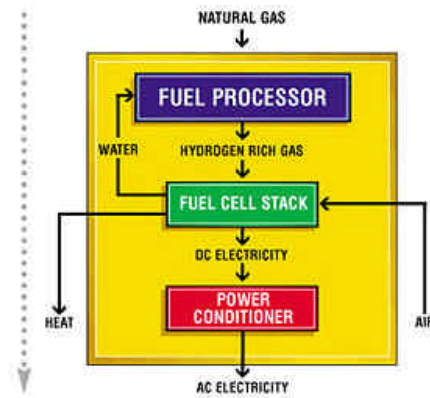


Figure 4-Fuel Cell Components Diagram

2.5.1.1 Fuel Processor

The fuel processor is used to convert liquid hydrocarbon fuels to hydrogen for fuel cells. The type of processor used for our system utilizes the heat and mass transfer qualities that are exhibited when fluids flow in and around microstructures. Each microstructure contains machined micro-channels engineered to enhance chemical reactions. The process operations units are embodied in parallel sheets that are machined with many micro-scale features. Combinations of reactor, heat exchange, and control sheets are stacked together to form an integrated system that performs needed operations to process the fuel. (Micro Chemical and Thermal Systems 2000)

2.5.1.1 Fuel Cell Stack

The fuel cell stack is composed of many fuel cells containing membrane electrode assemblies sandwiched between bipolar collector plates. The collector plates have channels that assist in directing the fluid flow throughout the stack. An end plate is used on both sides to complete the plate.

The membrane electrode assembly within each fuel cell uses a proton exchange membrane sandwiched between a positive and negative electrode. Hydrogen rich fuel is passed through the channels of the bipolar plate on the negative electrode side (anode) while air is fed through the channels on the positive electrode side (cathode). The catalyst is used to encourage the hydrogen to divide into protons and electrons. The electrons then pass through an external circuit, creating electricity. The protons pass through the membranes

combining with the electrons and oxygen on the other side to create water and heat (Energy Partners 2000)

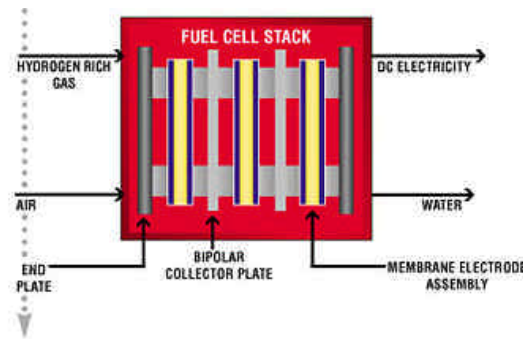


Figure 5-Fuel Cell Stack

2.5.1.3 Power Conditioner

A power conditioner is used within a fuel cell system to convert the obtained electricity from direct current (DC) to alternating current (AC). Our ionic propulsion drive utilizes direct current, therefore; the power conditioner is not needed for our fuel cell system.

2.6 Sensor and Control Systems: (Pascal)

2.6.1 Flight Control System

As for a manned vehicle, the flight control system of a UAV is required to provide semi-autonomous take-off, landing, hover, steering, and fully autonomous or remotely piloted flight. By the dynamically re-tasking flight capabilities through 4 main plug & play components, the control system guides the vehicle controlling its motion around the pitch, roll, yaw axis as well as forward and vertical axis.

The 4 specific tasks dedicated to the Flight Control System are:

- **SENSORS:** Used for retrieving all the flight references, parameters (air velocity, temperature, pressure...) and the actual platform attitude (heading...). Some specific sensors are included (cameras) for the navigation system.
- **NAVIGATION SYSTEM:** This system is in charge of providing all the orders necessary to maintain the vehicle on its desired path. It collects information from the sensors and a specific navigation system that processes a flight path in real time.
- **AUTOMATIC FLIGHT CONTROL COMPUTER:** As the main component of the flight control system, the AFCS is in charge of translating navigation commands in specific mechanical orders for the actuators. Moreover, all the automatic flight capacities required by the navigation system are handled by the AFCS.

- **ACTUATORS:** As the last part of the flight control system chain, the actuators are the mechanical devices that give control surfaces a desired position, or a specific blade pitch angle.

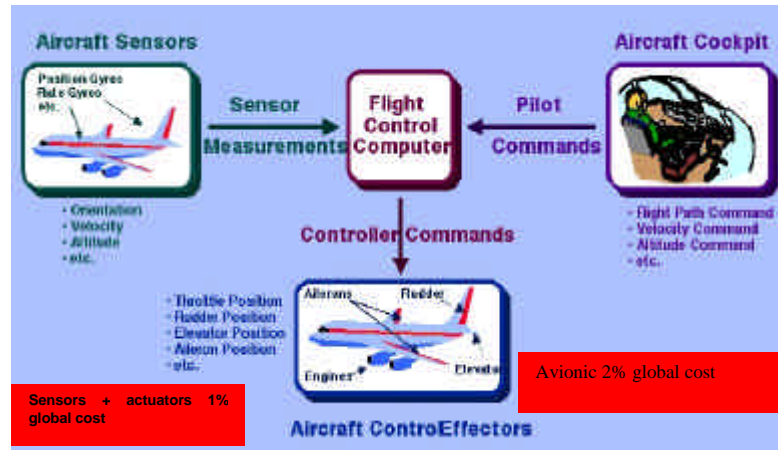


Figure 6-Flight Control System

By using actual technology for AFCS, actuators and sensors, GRAD Inc. provides a low cost, robust and accurate system (sensors & actuators: <1% global cost; avionics: <2% global cost). All path commands are processed by a totally innovative, fully autonomous with no external references and passive navigation system based on imaging treatment.

Table 3: Flight Control System Technology Analysis

	SENSORS	NAVIGATION	AFCS	ACTUATORS
COST	+	-	+	+
WEIGHT	+	+	+	+
RELIABILITY/ ROBUSTESS	+	+	+	+
DEVELOPMENT RISKS	+	-	+	+

Grad Inc will use electrical technology for sensors providing a well-known and reliable system. Actuator layout will be defined by aerodynamics and will control aerodynamic surfaces as well as engine thrust vector.

2.6.2 Sensors

Mostly used by the navigation system, the vehicle sensors are based on typical aircraft sensors (inertial measurement unit, air control...) and a camera based viewing system for 3D map generation in all weather and battlefield conditions.

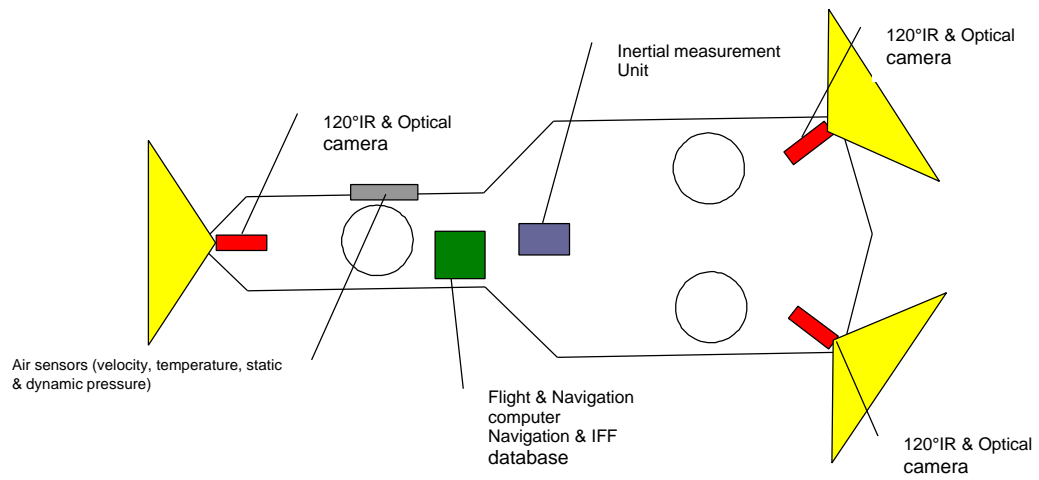


Figure 7-Navigation and Controls Sensors Layout

Table 4: Sensors for Navigation and Controls

SENSOR	INFO CHARACTERISTICS	SIZE	WEIGHT	POWER	COST
IR CAMERA	500-1000 fps 510*246 pixels	7*9*22 (cm) 2,7*3,5*7,8 (inches)	1.6 kg (3,5 lbs)	28 VDC 0,5 A	1% global cost
OPTIC CAMERA	500-1000 fps 510*246 pixels	7*9*22 (cm) 2,7*3,5*7,8 (inches)	1.6 kg (3,5 lbs)	28 VDC 0,5 A	
AIR SENSORS	Temperature, Velocity, total and static pressure	< 15 in ³	NA	28 VDC	
INERTIAL MEASUREMENT UNIT	RING LASER GYRO A/C ATTITUDE	< 200 in ³	<10 lbs	28 VDC	
ENGINE SENSORS	NA	NA	NA	28 VDC	

All information and characteristics contained in Table 4 are based on existing aeronautic devices. In ten years, these characteristics will be reduced in a significant way in terms of mass and volume. The most important reduction will be seen in the field of visual technology. All other devices, such as computing devices, will still be heavier and larger than what you find on ground due to armored requirements.

2.6.3 Navigation System

The UAGV requires a system that processes current vehicle conditions and commands the flight control system in order to provide the desired flight path and correct attitude for the vehicle. The navigational specifications for the control of the UAGV are based on discretion, accuracy in the followed flight path as well as collision avoidance, air motion capability, and autonomous capability. This lead GRAD Inc. to invent a new and innovative navigation system based on image processing and a real time 3-dimensionnal map comparison. Such a system is able to process flight path commands as well as the true flight path. The true flight path may be updated in real time due to the evolution of threat or new objective assignment. The navigation system is the main brain of the vehicle, processing the local environment and desired objectives to obtain the fastest, safest autonomously. It will be reinforced with a classical low cost/weight inertial navigation system and a redundant human remote control mode.

The key components and functions for the navigation system are:

- Fully autonomous flight/ground path processing with no external aids (No GPS)
- Obstacle avoidance capability essentially for ground motion
- Real time flight path update for terrain/threat environment evolution
- 3 120° optical & infrared cameras
- Database and computer

The navigation system is based on a 360° real time stereoscopic view of the terrain. This image is processed in real time to get a 3-dimensional map of terrain with specific algorithms obtaining altitude and distances from viewed objects. A reference 3-dimensional map is stored in the navigation system and a desired flight path is drawn on this map. This reference flight path may be updated in real time, and processed to achieve mission objectives. The comparison of both the reference flight path and the true flight path by superimposing the two maps give the navigation system all the data necessary to process commands for mission objective.

The major advantages of such a system are:

- Capability to change its path due to threat evolution.
- Capability of maintaining fully autonomous capacity
- Capacity to send a 3 dimensional local view of the terrain for remote capability
- Capacity to share information with other terrain sensors
- All conditions (weather, time, obscurants) **passive** system

The major drawback of this system is the huge processing power and data storage required to process in real time. Foreseen evolution of the computing power in the next 10-25 years, due to Moore's law (Chip performance increases twice every 2 years), makes this concept totally feasible.

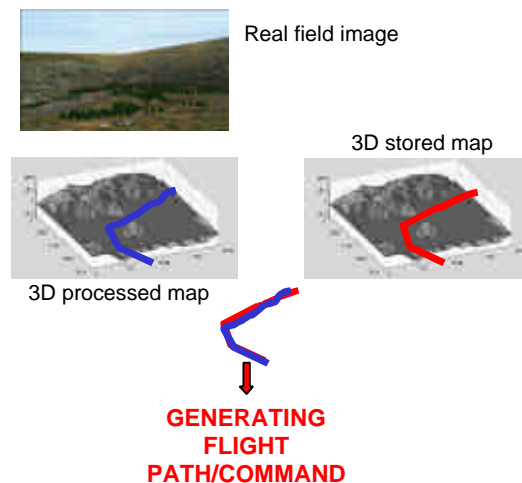


Figure 8: Process of Generating Flight Path Command

The same sensors are used for navigation and visual threat detection. For this reason a ground resolution of 10 centimeters (about 4 inches) is required for enabling of the cameras to detect weapons and small objects. A lower resolution may be considered (about half a meter) for navigation purposes to decrease the need of power processing. At 27 m/s (90 ft/s), such a system requires about 270 frames per second to detect details as small as 10 centimeters. Actually, it needs about 20,000 seconds to treat such an image. For real time processing, processing power must increase by a factor 10×10^6 .

The type of data storage support is yet to be defined. New development in computing technology makes the storage of a 10 centimeters resolution map of a huge area (several kilometers) totally feasible. Actually, based on Moore's law, all the navigation computing system (image processing, map storage, path processing) will fit in a volume lower than 7*5*14 inches (H*W*D), and a weight lower than 5 pounds for an equivalent cost of an actual flight computer.

It is possible to share processing power and data storage capacities with all other sensor, particularly with the IFF device, sharing visual information. The image-processing step will be able to create field mapping and treat all information of threat. This will be done by comparison with a remarkable on-board library of objects.

One of the major points of developing such a navigation system is its passive capability. This system is able to generate a path by looking only to its local environment without external references such as GPS or nav-aids.

2.6.4 Identification of Friend or Foe

GRAD Inc. has devised a top down, three-step test to detect whether an object is a friend or foe. The first step is to take a picture of the object in question and then compare it to a predefined database of objects that are of similar shape and size. If the comparison indicates that the object could be a foe the test increments to the second step. If the object is of friendly origin the test is reset. The second step is to take a thermal scan of the object in question. This scan is then compared to a database of known objects of similar shape and size. If this scan shows the object to be a foe the third step of the test is done otherwise the test is reset. The third step is to take an acoustic reading of the object in question. This signature is then compared to a database of known acoustic signatures. If this test indicates that the object is a foe then the system contacts the appropriate personnel for further instructions.

2.6.5 Artificial Intelligence; thinking process

Its innovative navigation system will give the Patrocinor the ability to process a flight path and to adapt it according to the evolution of the threat on the terrain, by choosing the fastest, safest path according to mission priorities. But an unmanned must have a certain degree of autonomy to react according to mission priorities and changes. The thinking process developed by GRAD Inc. is based on the priorities set forth in the specification. This top down thought process lists all the events that can occur during a mission, prioritizes them according to importance, and give a specific answer to each. This logical thinking will be performed by an on board computer that is processing several inputs from various locations.

The major issues that apply in this behavior are:

- Survivability
- Mission Resources
- Threat Sensing And Detection
- Communication Information

The most significant processes are:

- Threat Analysis Process Chart
- Loss Of Communication Process
- New Objectives Assignment Process
- Loss Of Navigation Process
- Loss Of Equipment Power Supply Process
- Loss Of Resources Process
- Loss Of Detecting Capability Process
- Loss Of Platform Control Process
- Survivability Process
- Self Destruction Process
- Navigation Process
- Obstacles Avoidance Process

Priority is given to sensing and communication modes with a certain degree of discretion in case of immediate threat. Navigation focuses on survivable path processing to direct the UAGV as close as possible to the primary objectives. Local Threat in route may lead to primary objective or flight path changes in real time. Self-destruction capacity is taken into account in case of sensing and communicating mode failures and mission resources prevented from escaping an immediate threat. To ensure achievement of UAGV primary goals (sensing and analyzing threat on a battlefield), priority is given to payload mission objectives. The prioritization of the top-down thinking process for the UAGV is given in Table 5.

Table 5: Top-Down Thinking Process System

CONTROLS/NAVIGATION		
SENSORS	Optical camera	9
	Infrared Camera	9
	Inertial Measurement Unit	8
	Air Sensors	8
	GPS	0
	Laser Altimeter	6
	Engine sensors	8
AFCS	Flight Computer	9
	Remote Control	9
ACTUATORS	Actuators	
		8
NAVIGATION SYSTEM	Navigation Computer	10
	Navigation Database	10

By using a dense array of Ultra Wide-Band (UWB) receivers and transmitters, with the computing power to determine distance, size, and shape of equipment, GRAD Inc. can break beyond the limits of traditional radar. This array of UWB sensors will provide the customer it the ability to see objects hidden by almost any kind of barrier at short distances. As this technology increases the range will greatly increase.

The infrared sensors used within Patrocinor will provide the needed built in processing capabilities to approximately stand-alone with minimal support from a main processor. This should help to increase the accuracy and resolution of the sensors.

2.7 Communications: (Joe Caldwell)

The basic layout for the ground control station will be located within a HUMMVEE shelter. (Fulda 2001) This station will include items such as a data recorder, antenna, visual screens and a maneuvering and power control system. Each of these components will be used to maintain contact with the vehicle at all times during the mission.

The line of sight communications will be done using ultra wide band technology. This technology has some very substantial advantages over the systems currently used by the military. First, UWB transmits at ultra low levels in the neighborhood of 50 microwatts. Second, UWB uses a wide range of frequencies. This use of frequency increases the degree of difficulty for foreign systems to detect the exact frequency with which the UAGV is actually transmitting. UWB allows transmission of data at about 40 megabits (Mbps) per second (Mbps) and the traditional C-band transmitter transmits data at approximately 4 to 5 Mbps. UWB transmits digital pulses instead of basic sine waves. This form of transmission is advantageous to us because digital signals are easier to work with.

UWB is also very hard to jam due to its ability to use a wide band of the frequency spectrum. The opposition would have to approximately scan the entire frequency spectrum to determine where we are transmitting and would how to introduce 'white noise' over a very large area of the frequency spectrum. (Time Domain 2000) This is a very hard thing to accomplish.

For beyond line of sight communications, we intend to incorporate several different techniques. The link will consist of a ground based satellite transmitter that will communicate with a satellite to relay the information to the vehicle. The communication between the satellite and the vehicle will be sent by a highly encrypted UWB transmission. This link can then be used to change orders or tasks as required by the battalion.

The communication link at line of sight can also meet these requirements. The communication link between higher-ranking personnel that might be a far distance away from the mission will be accomplished through a ground based satellite link to communication satellites then transmitted to the decision-makers. The same process can be used in the reverse direction. There will be other ground to satellite links that will be necessary to get the correct information to and from the command center.

2.8 Ground Robotics: (Bryan Griffin)

Although the specification refers to the system as an unmanned aerial and *ground* vehicle, it does not actually require the system to have *ground mobility*. This being the case, ground robotics for the Patrocinor has been limited to a simple system consisting only of landing feet. The main advantages to this are reduced weight and reduced power requirements. The disadvantages are the inability to move to a different viewpoint of the mission target area without lifting off the ground. However, because of its quiet acoustic

signature, and its radar absorbing skin, the Patrocinator will be able to hover around the target area instead of moving on the ground and still be able to avoid detection.

The landing struts will be fabricated from the same material as the body of the Patrocinator. The extending/retracting mechanism consists of a pneumatic air cylinder that will be fed by a high-pressure composite vessel. Composite compressed air cylinders can hold air at up to 6000 psi that will facilitate operation of the landing struts for several missions before being refilled. The risk of damage in the event of a cylinder rupture is low because the composite wrapping allows the cylinder to decompress without a catastrophic explosion. This system will enable Patrocinator to land in unprepared areas. In the event of a system failure, the Patrocinator will still be able to return to its point of origin and land on the underside of the vehicle without using the struts due to the fact that the ionic propulsion system does not have moving parts.

2.9 Materials: (FX)

The monocoque structure, shown in Figure 9, of the Patrocinator insures tremendous strength and durability, and eliminates the need for a substructure. The monocoque is an exoskeleton designed using a layered composite skin. The first layer is an epoxy/carbon fiber structure. The skin derives most of the strength from this layer. The second layer is a photo-chrome layer. This layer enables The Patrocinator to morph its color to match the surroundings. The final layer is an anti-radar material currently used by the military. The 3 layer composite skin is approximately 0.2815405in ($\approx 7.15\text{mm}$) thick and weighs about 53 Lbs. ($\approx 24\text{kg}$) total. Table 6 is an example of material properties for a similar composite skin.

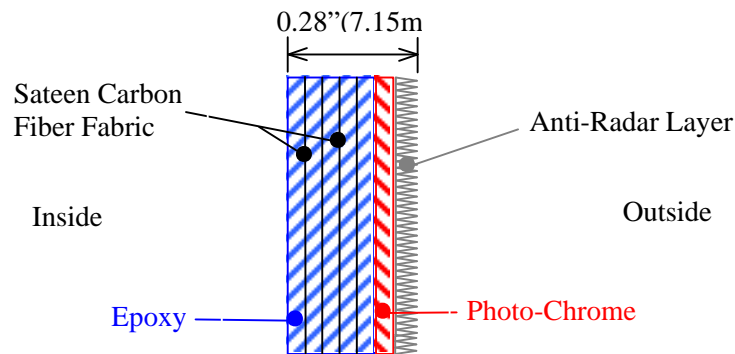


Figure 9: Monocoque Structure

Table 6: Example of an actual Epoxy/Carbon fiber composite material.

{PRIVATE}PHYSICAL PROPERTIES VALUES				COMMENTS	US / Other Units
Density,		g/cc	1.6		1.6 g/cc
MECHANICAL PROPERTIES VALUES				COMMENTS	US / Other Units
Tensile	Strength,	Ultimate,	MPa	2100	304,580 psi
Modulus	of	Elasticity,	GPa	170	In tension 24,656 ksi
Compressive	Yield	Strength,	MPa	1720	249,465 psi
Shear	Strength,		MPa	120	17,405 psi
THERMAL PROPERTIES VALUES				COMMENTS	US / Other Units
Thermal	Conductivity,		W/m-K	9	62 BTU-in/hr-ft²-°F

The fiber structure:

This is the layer that gives Patrocinor its strength and it is to this layer that all the internal parts of the concept are attached. The first concept was to employ Bore Fiber (used on the US Navy F-14 Tomcat), however this kind of fiber can only be used unilaterally, it is very expensive, and hazardous to use. We have hence decided to use Carbon Fiber HM (High Module) as an alternative. Table 7 lists the properties of the just Carbon Fiber.

Table 7: Material Properties of Carbon Fiber

Density (kg/m ³)	1.8
Modulus of Elasticity E (Gpa)	420
Tensile Strength, ultimate σ (Mpa)	3500
Plastic Limit % ($\Delta L/L$)	0.8%
Maximum H ₂ O absorption	0.2%

The assets of carbon fiber are:

- Low Weight
- High Strength
- Handles both Tension and Compression Stresses
- Doesn't Absorb Excessive Water During Manufacturing
- Low Material Density

The drawbacks of carbon fiber are:

- Difficult to manufacture
- Price (about 15,000 francs/kg \approx 1,200 US\$/Lbs.)
- Shock sensitive
- Risk of skin illness
- Galvanic chemical reaction with aluminum

Moreover the United States is the second largest producer of carbon fiber in the world (behind Japan), accounting over for 30% of the world's supply. There are various methods to create the carbon fiber matrix. The method that has the highest strength is to weave the fibers similar to the weave pattern of sateen. The overall carbon fiber matrix will use a thermosetting epoxy (density about 1.2).

Assets:

- High Adhesive Strength
- Non-Shrinking
- Easy to Manufacture
- Wears Over Time

Drawbacks:

- Cost
- Toxicity During Manufacturing
- Might Ignite During Manufacturing

The best process to manufacture composite Carbon fiber/Epoxy is to use an Autoclave. However there are new processes being developing, and should be efficient by 2020. Once such process is called SCRIMP (Seemann Composite Resin Infusion Molding Process). Like an advanced version of the Autoclave, this process bakes the material under extreme pressure and removes the micro-air bubbles and solvents by an intense vacuum. This technology is used on fighter jet ailerons and Formula 1 shocks.

Carbon fiber/epoxy composites have a density of about 1.6 g/cc which, when compared to metals like Titanium (4.50 g/cc), is relatively light. Scientists working on composite materials believe that by the year 2025 they should be able to reduce the density of the material to 1.2 g/cc with the same strength. Using this assumption and the estimate of surface skin of 10,000 inch² (6.4516m²), we found determine with a skin about 0.07874 inch thick (\approx 2mm) the structure and skin weight about 34.2 lbs. (\approx 15.5kg) (www.matweb.com).

The cost of the carbon fiber layer will be 42,000 US\$ per unit for materials. An autoclave oven (or SCRIMP) adds at least 200,000 US\$, however many facilities already exist. It takes about an hour to prepare the fabric for 1 lb. of material and one day to bake the entire skin.

The photo-chrome layer (the chameleon layer):

This layer uses color morphing technology based on photochemical reactions: heterolytic or homolytic cleavage, isomerisation of the double bonds C=C, tautomerisation. The photo-chrome plastics are spiropyranes, spiroxazines, and triarylmethanes. This layer would change the camouflage of the vehicle automatically: the upper part would adapt the

color of the ground while the lower part would blend with the sky. This layer will be about 0.0059055 inch thick ($\approx 0.15\text{mm}$) and weight about 0.84 Lb. ($\approx 381\text{grammes}$)

The assets of this technology are:

- All the colors are possible with the same skin
- The layer is able to change color in 100s (supposed to be 30 seconds by 2020)

The major drawback is this material degrades over time and would need to be replaced every few years.

The anti radar layer:

This layer needs to be transparent so the chameleon layer underneath shows through. It is made of a special radar absorbing plastic. The shape, depicted in Figure 10, is designed to capture radar waves inside the skin and redirect them when they are reflected back (technology used on the F-117 and B-2). This radar-absorbing layer lowers the radar cross section and improves the vehicle's stealth capabilities.

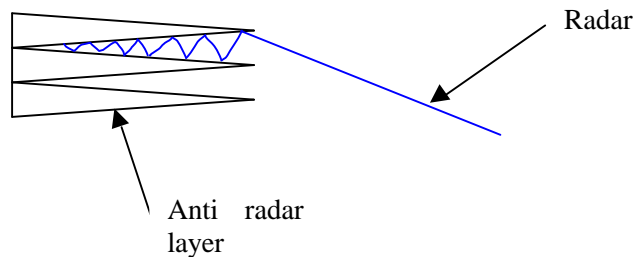


Figure 10: Anti Radar Layer

This layer is 0.1969in ($\approx 0.5\text{cm}$) thick and weighs about 18 lbs. ($\approx 8\text{kg}$). This technology does exist, however it's still classified material and therefore difficult to obtain detailed information. As the US Air Force already uses this technology it will be easy for our customer (AMCOM) to gain access to the information we are missing.

2.11 Technical Summary (Younes)

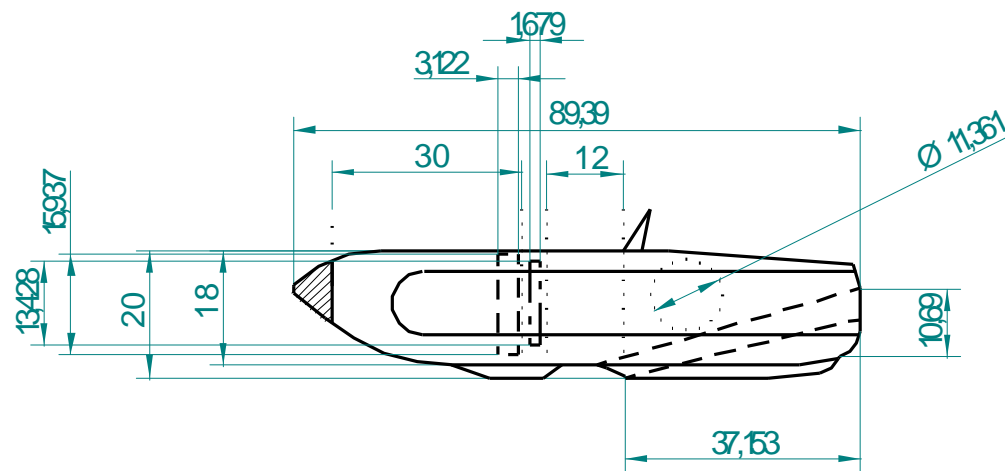


Figure 11- Cross Sectional Drawing

Table 8: Concepts Technical Information

Comparison Criteria	Proposed Concept
Overall Specifications	
Air Configuration	Ionic Propulsion
Ground Configuration	Hover
Payload Mass, kg (lb)	60 lbs.
Gross Takeoff Weight, kg (lb)	300 lbs
Energy Source for Air Transport	PEM Fuel Cell
Energy Source for Ground Transport	PEM Fuel Cell
Hovering Power, Kw (hp)	22.04 kW(30.0 hp)
Cruise Power at 15 km/hr , Kw, (hp)	23.81 kW (31.93 hp)
Total Energy for Mission Profile, KJ (BTU)	2.564×10^5 KJ (2.43×10^5 BTU)
Basis of Autonomy	Thinking Process
Primary BLOS Method	Ultra Wide-Band
Primary Structural Material	Carbon-Fiber
Enabling Technology 1	Ionic Propulsion
Enabling Technology 2	Fuel Cells
Enabling Technology 3	Ultra Wide-Band
Enabling Technology 4	Vehicle Skin
Team Selected Category 1	Ionic Propulsion
Team Selected Category 2	Ultra Wide-Band
Team Selected Category 3	Fuel Cells

3.0 Implementation Issues

The major implementation issues foreseen for this project are those that involve the development of fuel cell technology and ion propulsion. Current fuel cell technology meets some but not all of the requirements set forth by the vehicle design. While the power consumption of the vehicle can be met with current technology, the weight limits that were established cannot. Given the recent developments in fuel cell technology and predictions by current developers it seems that within the next twenty years the power and weight requirements can be met to the satisfaction of the current design specifications.

Ion propulsion, although having been developed for quite some time, is still in its infancy. Proper development for use as a vehicle propulsion device has not reached its full potential. The means to develop this technology exists and must be fully investigated and studied in order to put ion propulsion to practical use. Despite these minor implementation issues, the project schedule should be met in sufficient time to qualify for the technology readiness date established for product delivery.

3.1 Programmatic Ground Rules and Assumptions

When any project of such an advanced nature is under taken, technology becomes the number one priority. With the strong advancements in the fields of electronics, fuel cells, and propulsion it can be difficult to ascertain what may and may not be beneficial to the project. For any project to be successful there must be a fine balance between completing the design on time and integrating the latest technology into the system design.

With a technology readiness date of 2025 we can expect great changes in current technologies. More specific to this project would be ion propulsion and fuel cells. Some assumptions on power consumption and fuel cell weight have been based on current technology data. Given the rate at which these technologies have advanced to date, it seems that power and weight assumptions can be met or will exceed the standards that have been set forth by this project.

3.2 Work Breakdown Structure

- 1.0 UA/GV Program
- 2.0 UA/GV System
- 3.0 AV/GV Subsystem
 - 3.1 Project Manager
 - 3.2 Programmatics
 - 3.2.1 Costs
 - 3.2.1.1 Enabling Technologies
 - 3.2.1.1.1 Automated Computer Program for Spreading Technology Costs
 - 3.2.1.1.2 Breadboard
 - 3.2.1.1.3 Brass board
 - 3.2.1.1.4 Flight Demo
 - 3.2.1.1.5 Prototype
 - 3.2.1.2 Phase 0
 - 3.2.1.2.1 System Analysis
 - 3.2.1.2.2 Requirements Definition
 - 3.2.1.2.3 Conceptual Design
 - 3.2.1.2.4 Cost Risk Assessment
 - 3.2.1.2.5 Performance
 - 3.2.1.3 Phase I
 - 3.2.1.3.1 Conceptual Design
 - 3.2.1.3.2 System/Subsystem Trades
 - 3.2.1.3.3 Preliminary Design
 - 3.2.1.3.4 Prototyping Test and Evaluation
 - 3.2.1.3.5 Integration of Manufacturing, support, and Operations into the Design
 - 3.2.1.4 Phase II

- 3.2.1.4.1 Detail Design
 - 3.2.1.4.2 DDT&E
 - 3.2.1.4.3 Risk Management
 - 3.2.1.4.4 Development Tests and Evaluation
 - 3.2.1.4.5 Systems Integration, Tests, and Evaluation
 - 3.2.1.4.6 Manufacturing Processes Verification
 - 3.2.1.5 Phase III
 - 3.2.1.5.1 Production Rate Verification
 - 3.2.1.5.2 Operational Tests and Evaluation
 - 3.2.1.5.3 Deployment
 - 3.2.1.5.4 Operational Support and Upgrades
 - 3.2.1.5.5 Retirement
 - 3.2.1.5.6 Replacement Planning
 - 3.2.1.6 Disposal
- 3.2.2 Schedule
 - 3.2.2.1 Enabling Technologies
 - 3.2.2.1.1 Automated Computer Program for Spreading Technology Schedule
 - 3.2.2.1.2 Breadboard
 - 3.2.2.1.3 Brass board
 - 3.2.2.1.4 Flight Demo
 - 3.2.2.1.5 Prototype
 - 3.2.2.2 Phase 0
 - 3.2.2.2.1 System Analysis
 - 3.2.2.2.2 Requirements Definition
 - 3.2.2.2.3 Conceptual Design
 - 3.2.2.2.4 Cost Risk Assessment
 - 3.2.2.2.5 Performance
 - 3.2.2.3 Phase I
 - 3.2.2.3.1 Conceptual Design
 - 3.2.2.3.2 System/Subsystem Trades
 - 3.2.2.3.3 Preliminary Design
 - 3.2.2.3.4 Prototyping Test and Evaluation
 - 3.2.2.3.5 Integration of Manufacturing, support, and Operations into the Design
 - 3.2.2.4 Phase II
 - 3.2.2.4.1 Detail Design
 - 3.2.2.4.2 DDT&E
 - 3.2.2.4.3 Risk Management
 - 3.2.2.4.4 Development Tests and Evaluation
 - 3.2.2.4.5 Systems Integration, Tests, and Evaluation
 - 3.2.2.4.6 Manufacturing Processes Verification
 - 3.2.2.5 Phase III
 - 3.2.2.5.1 Production Rate Verification

- 3.2.2.5.2 Operational Tests and Evaluation
 - 3.2.2.5.3 Deployment
 - 3.2.2.5.4 Operational Support and Upgrades
 - 3.2.2.5.5 Retirement
 - 3.2.2.5.6 Replacement Planning
 - 3.2.2.6 3.2.1.6 Disposal
- 3.3 Systems Integration
 - 3.3.1 Requirements & Specifications
 - 3.3.1.1 AMCOM revised specification #2
 - 3.3.2 Interface Control
 - 3.3.2.1 N/A
- 3.4 Aerodynamics
 - 3.4.1 External
 - 3.4.1.1 Blended body structure
 - 3.4.1.2 Retractable wings
 - 3.4.1.3 Rotorcraft
 - 3.4.1.4 Fans and turbines
 - 3.4.2 Internal
 - 3.4.2.1 N/A
 - 3.4.3 Structure
 - 3.4.3.1 Carbon Fiber
 - 3.4.3.2 Bore Fiber
 - 3.4.3.3 Kevlar
- 3.5 Propulsion & Drive
 - 3.5.1 Propulsion
 - 3.5.1.1 Magneto Ion
 - 3.5.2 Drive
 - 3.5.2.1 Hover
 - 3.5.3 Power
 - 3.5.3.1 Fuel Cell
- 3.6 Ground Robotics
 - 3.6.1 Artificial Intelligence
 - 3.6.1.1 Virtual Reality
- 3.7 Acoustics & Control
 - 3.7.1 Acoustics
 - 3.7.1.1 Limited radar cross section
 - 3.7.1.2 Controlled exhaust heat signature
 - 3.7.1.3 Noise and vibration dampening
 - 3.7.2 Control
 - 3.7.2.1 N/A
- 3.8 Sensors & Communication
 - 3.8.1 Sensors
 - 3.8.1.1 Active Radar
 - 3.8.1.2 Infrared radar
 - 3.8.1.3 Radar
 - 3.8.1.4 IFF

- 3.8.2 Navigation
 - 3.8.2.1 Altitude
 - 3.8.2.2 Air speed
 - 3.8.2.3 Direction
 - 3.8.2.4 Position
 - 3.8.2.5 Vision
 - 3.8.2.6 Hearing
 - 3.8.2.6.1 Ultrasonic
 - 3.8.2.6.2 Acoustic
 - 3.8.2.7 Sight
 - 3.8.2.7.1 Thermal
 - 3.8.2.7.2 Terrain recognition
- 3.8.3 Communications
 - 3.8.3.1 Predator

3.3 Life Cycle Schedule

Figure 12 is the proposed life cycle schedule of the project. The following table, 3 is the tentative breakdown of the scheduled tasks.

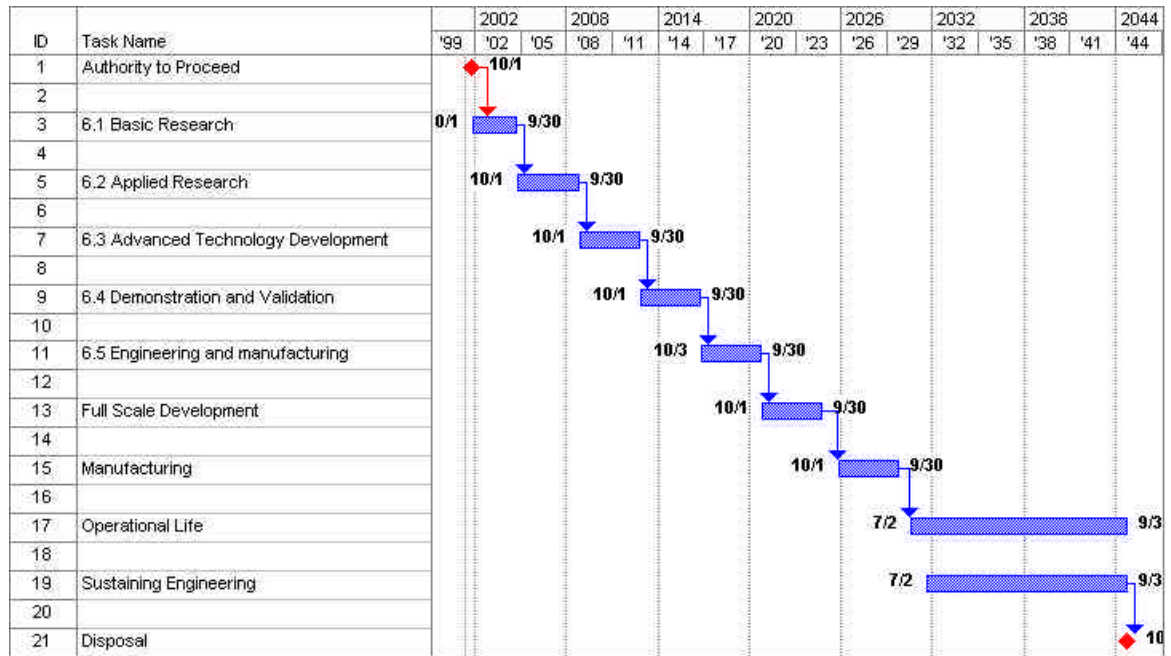


Figure 12-Overall Technology Development Schedule

Table 9. Breakdown of Scheduled Tasks

Task	Time Frame
Basic Research	10/01/01 – 9/30/04
Applied Research	10/01/04 – 9/30/08
Advanced Technology Development	10/01/08 – 9/30/12
Demonstration and Validation	10/01/12 – 9/30/16
Engineering and Manufacturing Development	10/01/16 – 9/30/20
Full Scale Development	10/01/20 – 9/30/25
Manufacturing	10/01/25 – 9/30/30
Operational and Sustaining Engineering	10/01/25 – 9/30/50
Disposal	10/01/50 – 9/30/55

3.4 Life Cycle Costs

Table 9 shows the project breakdown in years and the estimated project cost at that point in time. Refer to Figure 13 for project total life cost estimations. These figures represent project development costs as incurred by the project over the entire project life. The total project development cost was estimated to approximately \$225 Million dollars.

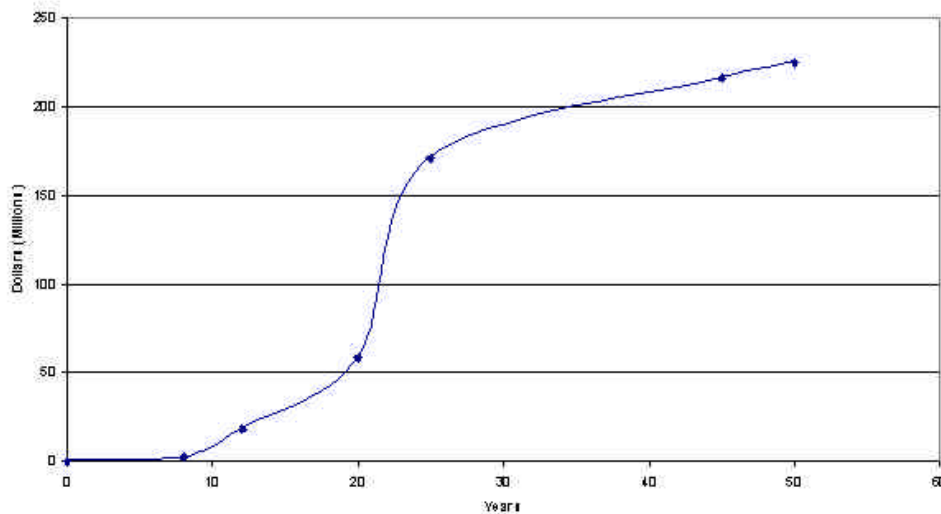


Figure 13--Phase of Project VS. Incurred Costs

3.5 Risk Analysis (Kodrowski)

Moderate risk exists in the design of the Patrocinator. The majority of the risk comes from the propulsion system. Theory for the ionic propulsion system is sound and verifiable but due to the different application of the theory that is necessary for this design there is little data to compare the theory too. Tied into the propulsion system is the power supply for the propulsion and communication systems. Fuel cells contribute the other risk to the Patrocinator. Currently there have been major developments in fuel cell technology and there is little doubt that within the ten-year technology time frame fuel cells will be able to exceed the power requirements that are used in the design of the Patrocinator. Virtually all of the other major components are low risk. Therefore the combined risk of all systems that comprise the design of the Patrocinator amount to a moderate risk that is dependent upon the development of really only one major component.

3.6 Discussion of Application and Feasibility (Kodrowski)

Summarize simplicity of manufacturing considerations, realism of technology levels, advantages and disadvantages of proposed design in relation to requirements, additional applications other than RFP, environmental impact, social acceptance, and cost effectiveness.

4.0 Company Capabilities (Nathan Smith)

Global Research and Development consistently demonstrates excellent teamwork and communication skills. Each team member introduces innovative ideas to include in the overall company mission. Although each member specializes in a specific field, they are still capable of joining ideas and designs in an interdisciplinary effort to aid in the accomplishment of specific tasks. Each member interacts with their French counterpart in an effort to achieve defined goals in a timely and productive manner. Members also interact on a regular basis with professional personnel to gain insight and guidance relating to specific fields.

4.1 Company Overview (James Kodrowski)

Global Research and Development Inc. is comprised of a diverse group of engineers and managers. We draw on the skills of people versed in many different areas of specialization. With much enthusiasm and cooperation, GRAD Inc strives to take on the challenges presented by our customers.

During the RFP phase of this project, GRAD Inc. developed a solid plan for development of the UAGV system. Additionally, GRAD Inc. developed strong relations with ESTACA. Using ESTACA as our prime materials and acoustics members, we showed the capability of GRAD Inc. to work closely with the contractor while maintaining high quality and professionalism.

Our ability to communicate the ideas necessary for the UAGV project completion is evident in the technical presentations delivered by GRAD Inc. during both Phase I and Phase II of the UAGV project. Our team showed their communication skills during Phase I by managing the Baseline Design. Nathan Smith acted as project manager for the baseline, while the remaining members served as discipline heads for the Phase I development. Our alternate concepts presentation, which concluded Phase II, was delivered by Jason Back, James Kodrowski, and Sheree Long. Following this presentation these team members demonstrated their ability to field and answer questions related to the alternate concepts.

GRAD Inc. also showed an ability to manage communications with overseas counterparts, relaying ideas and completing tasks before deadline. This team successfully used the Internet to communicate their ideas with our partners in France, AMCOM personnel the team mentors, and individual team members.

4.2 Personnel Description

- **Mr. Bryan Griffin – Ground Robotics**
Mr. Griffin has shown a strong understanding of ground robotics throughout the three phases of this project. His expertise enabled the team to configure a suitable ground system for the aircraft.
- **Miss. Sheree Long – Mechanical Configuration**
Miss. Long has demonstrated superior ability to deal with complex problems related to the mechanical configuration of the aircraft. She also, with her organizational skills and

strong commitment to this project, was able to keep the team enthusiastic and focused, which made her a great asset to the team.

- **Mr. Joe Caldwell – Communications**
Mr. Caldwell's background in communications enabled Grad Inc to put together a very sophisticated communications system for the vehicle, which promises a great victory to his team over competition. He was also an important source of ideas for his team.
- **Mr. Kanna Krishnasamy – Aerodynamics**
Mr. Krishnasamy's ability to research and study problems has made him an essential member of the aerodynamics discipline and to the team as a whole. He has been contributing to his team throughout all phases of this project, which reflects on the great performance of the team.
- **Mr. James Kodrowski – Systems Integration**
Mr. Kodrowski's knowledge has allowed him to be a major contributor in many aspects of this project. His research and initiative are personal strong points, which are a key to improving the design considerations of the Ion Defender.
- **Mr. Nathan Smith – Project Office/Team Leader**
Mr. Smith's leadership and organizational skills made him an excellent choice for heading the team. He contributed a lot with his knowledge to all different disciplines within his team, which made him a key asset to all of them.
- **Mr. Akmal Abdulakhatov – Aerodynamics**
Mr. Abdulakhatov's background in aerodynamics and ability to research has allowed him to contribute tremendously to his team. With his great ideas, the team was able to configure a winning design for the Ion Defender.
- **Mr. Jason Back – Propulsion/ Drive**
Mr. Back's knowledge of propulsion systems has made him a valuable asset to his team. He was able to research and design a very advanced propulsion system for the Ion defender. He also demonstrated a great ability in communicating with his teammates from different disciplines.
- **Mr. Younes Elkacimi – Aerodynamics/ Propulsion**
Mr. Elkacimi has demonstrated a great ability in dealing with various problems pertaining to aerodynamics and propulsion. His role as a team member allowed him to showcase his abilities. His knowledge made him a great source of creative ideas for his team.
- **Mr. Pascal Vidal – Controls/ Sensors**
Mr. Vidal's background in Controls and sensors enabled him to put together a great controls system for the aircraft. He was able to study and perform a thorough research on different control and sensor systems. He was a very dependable and enthusiastic team member.

- **Mr. Matthew Harris – Documentation**
Mr. Harris's skills and discipline have been important in consolidating all the different disciplines' ideas into a manageable and meaningful way. He has contributed with his knowledge to the improvement of the aircraft, which made him a reliable asset to his team.
- **Jean-Emmanuel Bzdrega-Navigation and Controls**
Mr. Bzdrega is a French student from ESTACA (Aerospace & Automotive Engineering 5-year program) who is an off-site GRAD Inc member. He specializes in Servo-controls & aerospace engineering and works with the Navigation & Controls team for Grad Inc in. Now in fourth year of the program, he will graduate with a master equivalency in July 2002.
- **Julien Geffard-Acoustics**
Mr. Geffard is also a French student from ESTACA specializing in acoustics. He provides GRAD Inc. At the team the acoustics specialist for GRAD Inc. He will graduate from a French civil engineer degree (Master) in July 2002.
- **Francois-Xavier Hussenet:**
Mr. Hussenet is the third off-site French ESTACA student involved in GRAD Inc. His specialization in Aerospace & Materials provides GRAD Inc. with knowledge of the latest in materials technologies for military vehicles. As an aircraft pilot, he is also able to give GRAD Inc a great knowledge in flight theory.

5.0 Summary and Conclusions [Required]

The Patrocinor provides AMCOM with a competitive solution to the requirements set forth in the specifications using innovative technologies and processes. The Patrocinor combines top down thinking with near quiet propulsion in a lightweight UAGV. Moderate risk is involved with the propulsion and power options used in the Patrocinor. However, all of the technology used is proven, though it may be young. Survivability for the vehicle is designed to be high and is accounted for in the structural design and back up systems. Cost estimates for the project do not exceed \$170 million, a reasonable figure considering the time frame as well as other high tech projects currently in development with the Army. The Patrocinor meets or exceeds all of the specifications required of the project. The Patrocinor is the next generation of UAGVs.

6.0 Recommendations [Required]

Development in fuel cell technology is essential to the success of the implementation for the Patrocinor. Also, Placement of critical components in the system is vital to

maintaining the high survivability that is possible with this design. Now that this concept has been presented to AMCOM it will be their challenge to sell the idea of a new propulsion method for military vehicles to the government. As was mentioned before, the technology has been proven and is capable of meeting the necessary requirements. It is also the recommendation of the group that the communications development attempts to achieve full real time VR override to maintain the safety of our troops in the event that the Patrocinor's sensors misinterpret the data they receive. Any time delay could be the difference between life and death.

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Appendix A - Concept Description Document

1. General Description of Operational Capability

1.1. Overall Mission Area

- 1.1.1. The system shall be a versatile scout and pack animal for future force structures.
- 1.1.2. The system shall be capable for use for area/target reconnoitering.
- 1.1.3. The system shall be capable for use in terrain definition.
- 1.1.4. The system shall be capable for use in situational awareness.
- 1.1.5. The system shall be capable of both autonomous and semi-autonomous operation.
 - 1.1.5.1. The system shall be capable of human interface as required.
- 1.1.6. The system shall be capable of executing both a preplanned and an alter mission profile.
- 1.1.7. The system shall be capable of navigating and functioning without a payload.

1.2. Operational Concept

- 1.2.1. The system shall be capable of operation in a nap of the earth configuration.
- 1.2.2. The system shall be capable of operation at a range of 15-30 km from the launch point.
 - 1.2.2.1. The system shall be capable of gathering information on threat activities at range.
 - 1.2.2.2. The system shall be capable of enhancing the RSTA/BDA.
 - 1.2.2.3. The system shall be capable of transmitting information via secure data links and C2 structures BLOS.
 - 1.2.2.4. The system shall be capable of using TF/TA hardware and software to define and navigate complex terrain.
 - 1.2.2.5. The system may encompass a degree of AI, ATR, and on-board decision making.
- 1.2.3. Payload Requirements
 - 1.2.3.1. The system shall be capable of carrying a payload of 60lbs required gross weight, 120lbs desired gross weight.
 - 1.2.3.2. The system shall be capable of moving the payload to operational range in 30 minutes or less and be able to return from range in 30 minutes or less.
 - 1.2.3.2.1. The vehicle will have a minimum cruise speed of 30 km/hr and a desired speed of 100 km/hr.
- 1.2.4. Mission Requirements
 - 1.2.4.1. The system shall be capable of landing in an unprepared area
 - 1.2.4.1.1. The vehicle must have vertical takeoff and landing capabilities.
 - 1.2.4.3. The system shall maximize survivability.
 - 1.2.4.3.1. The system shall be capable of avoiding sonic detection.
 - 1.2.4.3.2. The system shall have a near quiet acoustic signature.
 - 1.2.4.3.3. The system shall be designed for an operational altitude of 0 – 500 ft AGL.
 - 1.2.4.3.4. The system must have a 250 fpm VROC, 500 fpm desired.
 - 1.2.4.4. The system must have a flight profile of hover to full flight.

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Current as of October 29, 2002

A-1

2. System Capabilities

- 2.1. The system shall be capable of operation at an altitude of 4000ft, 95 degrees Fahrenheit ambient temperature, and not using more than 95% intermediate rated power (IRP).
- 2.2. Operational Performance
 - 2.2.1. The system shall possess essential performance, maintenance, and physical characteristics required to operate under adverse environmental conditions worldwide.
 - 2.2.2 The system shall possess essential performance, maintenance, and physical characteristics required to operate under adverse geographical conditions worldwide.
 - 2.2.3. The system shall be capable of operating from any unimproved land or sea borne facility surface day or night, including low illumination.
 - 2.2.4. The system shall be capable of operation under battlefield obscuration.
- 2.3. The system shall possess the following electronic capabilities:
 - 2.3.1. Mission Planning System
 - 2.3.1.1. The system shall possess a point-and-click pre-mission planning system to simulate mission flight.
 - 2.3.1.2. The system shall possess data loading capabilities.
 - 2.3.1.3. The system shall be capable of coordination and reaction to immediate operational mission changes.
 - 2.3.1.4. The system shall be capable of processing self-awareness and threat sensor inputs.
 - 2.3.1.5. The system shall be capable of enabling TF/TA from digital mapping information from satellite or other sources.
 - 2.3.2. Avionics
 - 2.3.2.1. Communications and navigation suite architecture shall be compatible with emerging JCDL and/or JAUGS.
 - 2.3.2.2. Payload must be “plug and play.”
 - 2.3.3. Communications
 - 2.3.3.1. System communications shall be robust and have clear secure modes of operation
 - 2.3.3.2. Communications shall be simultaneously LOS and BLOS, which can include satellite relay or other relay system compatibility.
 - 2.3.3.3. System must possess IFF and be compliant to all FCC/military communication regulations.
 - 2.3.3.4. System must be capable of communication with and sharing digital mapping/targeting information with other DoD RSTA platforms.
 - 2.3.4. Connectivity
 - 2.3.4.1. The system shall be interoperable with other DoD systems envisioned for the 2025 battlefield to the maximum extent possible and be compatible with service unique C4I systems.

Appendix B - Alternate Concepts White Paper

IPT 3

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Programmatic/Marketing	Matthew Harris
Systems Integration:	James Kodrowski
Aerodynamics:	Younes Elkacimi; Kannathas Krishnasmy
	Akmal Abdul
Propulsion/ Drive:	Jason Back
Mechanical Configuration:	Sheree Long; Bryan Griffin
	Francois-Xavier Hussenet
Ground Robotics:	Bryan Griffin
Acoustics/ Controls:	Pascal Vidal; Jean-Emmanuel Bzdrega
	Julien Gefard
Sensors/ Communications:	Joe Caldwell
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Submitted By:

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Abstract

Advancements in technology have provided weapons that are smarter and far more deadly than ever before. In an attempt to preserve the lives of troops on the battlefield there exists the need for an unmanned vehicle which is capable of reconnaissance and data acquisition objectives and that can also transport small payloads into and out off enemy territory. In order to fulfill these needs, a compact and lightweight vehicle will be designed with reliability and survivability as the major focus. This paper proposes three systems and a baseline design, which have been considered as possible solutions for the problem. The first two systems are rotary aircraft types, which are based on current technology and design ideas. The second system is a hovercraft, which utilizes ducted fans for hover mode and rotate to produce forward flight. The third system is based on an innovative technology involving ionic propulsion. This system is based on current "Ionic Breeze" technology and produces a near quiet acoustic signature and no thermal signature. With future research and development it is possible that this technology will be adequate for use by the proposed roll out date.

Resumé

Les avancées technologiques de ces dernières années ont vu apparaître des systèmes d'armes de plus en plus sophistiqués et destructeurs. Dans un soucis de préserver les vies des soldats sur les champs de bataille, le développement de drones apparaît comme la solution idéale. Ces systèmes étant capables de missions de reconnaissance et de collectes d'informations stratégiques de manière autonome, tout en transportant une certaine quantité de charge utile en terrain ennemi.

Pour répondre à ces besoins, un drone léger et compact doit être développé en insistant sur les critères de fiabilité et de furtivité.

Ce document propose trois concepts répondant aux critères précédents en plus d'un concept de référence:

- Le premier reprenant les principes de l'hélicoptère est basé sur des solutions technologiques actuelles, ceci dans un soucis de facilité de développement et de réduction des coûts.
- Le deuxième concept reprend la technologie des aéroglisseurs, en utilisant des rotors carénés pivotants pour produire la poussée verticale et horizontale. Quoique plus innovant, ce concept reste basé sur des technologies éprouvées.
- Le troisième concept plus avant-gardiste, repose sur des technologies naissantes telle que la propulsion ionique et qui verront leur maturité dans les années à venir.

Ce drone est basé sur un système de propulsion original baptisé « souffle ionique » qui offre l'avantage d'une discrétion absolue en terme de signature acoustique et thermique.

Ce sont les prochains développement en matière de propulsion et de sources d'énergie qui rendront possible l'utilisation de ces nouvelles technologies pour une échéance à 10 ans d'un tel concept.

Technical Description

1.0 Overview of Phase 2

The Unmanned Air/Ground Vehicle (UAGV) sought by the U.S. Advanced Systems Directorate is envisioned to provide essential scouting and target recognition to the Brigade Commander. The customer and all participating teams endorsed a Concept Description Document (CDD) finalizing the customer requirements for this system on February 6, 2001. Phase 1 of the project produced one baseline concept that attempted to satisfy the project (CDD) using existing technology. GRAD Inc. at the University of Alabama in Huntsville has focused on synthesizing three alternative concepts. This White Paper provides a summary of the Baseline and our three alternative concepts. One of the concepts is selected for further development in Phase 3.

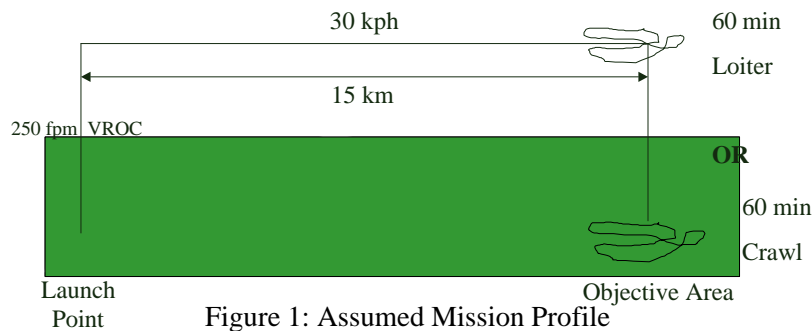
1.1 Specification Summary

Each of the proposed concepts by GRAD Inc. must comply with the following requirements. These requirements are proposed by AMCOM and give a general view of the vehicle's mission objectives including minimum and maximum requirements.

- Required 60lb payload gross weight
- Required to achieve operational range in minimum 30 minutes
- Required to return from range in minimum 30 minutes
- Required minimum cruise speed of 30 km/hr -- Desired speed of 100 km/hr.
- Required operation in Nap Of the Earth (NOE) configuration
- Required to takeoff/land in an unprepared area.
- Required to takeoff/land vertically (VTOL)
- Required 250 fpm Vertical Rate of Climb (VROC) -- Desired 500 fpm VROC
- Required operational altitude of 0 – 500 ft above ground level (AGL)
- Required operational altitude of 4000 ft at 95 °F
- Required maximum power consumption at 95% intermediate rated power (IRP)
- Required flight profile from hover to full flight
- Required capabilities for operation under adverse conditions worldwide.

The specification holds no mention of a mission profile for the UGAV pertaining to its capabilities or objectives. For the baseline, and duration of this project, a mission profile has been assumed. This profile states nothing about mission objectives and is based strictly on minimal criterion set forth in the specification (RFP). All parties involved, including the

customer, have reviewed the assumed profile and accepted it as a minimal basis for mission planning. Figure 1, illustrates the assumed mission profile.



1.2 Key Challenges

As part of the design, several points have to be taken into account during the designing phase. These points are the key factors of a well thought concept, including innovative and reliable technology as well as cost and development consideration.

First and foremost is power generation and the power to weight ratio. Producing enough power to sustain the unit while maintaining a near quiet acoustic signature at an efficient level will be key in survivability and feasibility issues. The survivability of the unit will also depend on the noise being produced from not only the power generation, but the sensor, communication, and propulsion units. Secondly, achieving beyond line of sight communication (BLOS) will be essential for maintaining an accurate picture of the battlefield. As always, producing each unit at a low final per cost will dictate the future this unmanned vehicle has on the battlefield.

The following are the main challenges GRAD Inc. has to face:

- Power Generation/Supply
- Power to weight ratio
- Stealth/Noise Signatures
- Beyond Line Of Sight (BLOS) Communications
- Cost

2.0 Description of Concepts

With a vehicle delivery date of 2025 there exists a sufficient amount of time for the development of new technologies that will greatly enhance our ability to design and build a small but smart vehicle capable of penetrating enemy defense perimeters and executing preplanned mission profiles. Major considerations in the development of these systems are cost and survivability.

The “Pawnee” was chosen as a baseline design for this project. This UAGV design is based on a typical rotorcraft configuration. Four wheels are utilized for ground mobility by adapting the same engine used to power the rotor system. Figure 1 of section 5 illustrates this design.

2.1 Concept 3A “PAWNEE”

Phase 1 developed the “Pawnee” concept. Due to the lack of time desired to complete Phase 1, several assumptions were made. The concept would be designed as a counter-rotating rotorcraft using current technology. Also the concept would have a target weight of 600 lbs and the ground system would use wheels. With an assumed rotor disk loading of 4 lbf/ft^2 a rotor diameter of 13 feet was estimated. The concept would need an engine with at least 91 horsepower to complete its assumed mission profile. The engine was a four-cylinder, JP-8, rotax manufactured by D-Star Engineering. The materials selected for the concept were lightweight and durable. The frame is made of a titanium alloy and the skin is a carbon fiber composite. The wheels are rubber with aluminum rims. The fuel tanks are also composite for lightweight. The sensors and communications for the Pawnee are LIDAR, C-Band, L-Band, and GPS & Inertial guidance. The total weight of the vehicle was an estimated 614 lbs. Overall the concept was a success, but it still did not meet all of the specifications set by the customer.

2.2 Concept 3B “Roto-Racer”

This concept, similar to the baseline, is comprised of a rotorcraft configuration. The design also utilizes a Wankel rotary engine (Ansdale) and retractable wheels. Even though this design is similar to the baseline, it weighs approximately two hundred pounds less. This design is illustrated in Figure 2 of section 5.

The Roto-Racer utilizes a conventional rotorcraft design. The Racer has co-axial, counter-rotating rotors that are made of strong, lightweight materials. Rotors are a proven method of vertical flight and should not provide any problem in the design. A Wankel type rotary engine is used to provide power for this vehicle. This engine was chosen due to its simple design, high power-to-weight ratio, and lightweight. This type engine is designed to run on unleaded gasoline, diesel fuel, or natural gas.

Rotorcraft aerodynamics incorporates conventional aerodynamics of the helicopter design with new advanced application of composite materials, power plant and controls system. The aircraft is built on a monocoque structure (a type of construction, as of a fuselage, in which the outer skin carries all or a major part of the stresses). This type of structure significantly reduces the weight of the vehicle. At the same time the survivability increases dramatically since there are no load bearing discrete structural members. In conventional frame design the whole structure can fail when critical frame elements are hit or damaged by foreign objects. The body is shaped to ensure the low drag profile. New technology allows impregnating sensors into skin and using it as radar.

Aerodynamic forces on the vehicle are dictated by the technical requirements of flight velocity, acceleration, and endurance. From known aerodynamic forces the power plant requirements are found. The best power to weight ratio is obtained using gasoline engines but the future developments show that small high output heavy organic fuel engine is desirable to have on the battlefield. The reason for this is that the “most of potential users of small propeller driven UAV’s are the military services. They have an established logistic chain for fuels and lubricants that does not include gasoline.” The main disadvantage of helicopter design is high noise coming from rotating blades.

The flight control and navigation systems are fully autonomous. The flight control and navigation system is based on a top-down process with input from several sensors and cameras (McLean). The vehicle is able to direct itself depending on its mission profile (Heller). There will be backup systems and redundant systems in case of any failure in any part of the sensor package (Moseby). Communication for this concept will implement ultra wideband technology for LOS and BLOS communications. These communications can be sent from the ground station or current military satellites.

The monocoque structure of this concept gives the concept tremendous strength and durability. The monocoque uses an exoskeleton design with a layered composite skin. The skin is layered with carbon fiber, bore fiber, electro-chrome, and radar absorbing material. The fiber structure is the strongest part of the skeleton. The electro-chrome layer absorbs electromagnetic radiation emitted from within the vehicle and outside the vehicle. Lastly the skin is covered with a radar-absorbing layer to lower the radar cross section adding to the vehicles stealth capabilities.

2.3 Concept 3C “Moth”

The Moth, illustrated in Figure 3 of section 5, is based on a blended wing body similar to that of the U.S. Air Force B-2 Bomber. This design incorporates two ducted fans for VTOL that pivot along the wing axes to provide forward thrust. No ground robotics were included in this design due to the ability of the ducted fans to provide enough maneuverability for “near earth” configuration. Figure 3 of section 5 illustrates the concept 3C design.

The Moth utilizes the most modern ducted fan technology. The blended wing design contains two ducted fans located in the middle of each wing. Each fan is capable of rotating within the wing housing to direct thrust from vertical to horizontal. Powerful electric engines power the fans, these fans are able create enough thrust to hold the Moth stable in hover. Also the fans can provide VTOL of at least 250 fpm. The blended wing helps create lift so the ducted fans can direct their thrust for horizontal flight.

A fuel cell is used as a power source for this system. Delphi Automotive Systems and Global developed the particular solid oxide fuel cell (SFOC) that was chosen. The cell stack configuration consists of four modules incorporated with a fuel reformer system in order to run the SOFC on automotive gasoline (Global). The SOFC produces up to 42 volts, has a power output of 3-5 kilowatts, and is practically pollution free.

The aerodynamics of the vehicle is incorporated for full-scale light aircraft. The ducted fans offer higher static thrust to horsepower ratio for a given diameter than open propellers. The ducted fan also shields the propeller from the harsh realities of the outside world, and the propeller "sees" air flowing in only one direction - front to rear. In fact, from the propeller's point of view it is not at rest at all, merely cruising at some fraction of its

The flight control and navigation systems are fully autonomous. The flight control and navigation system is based on a top-down process with input from several sensors and cameras (McLean). The vehicle is able to direct itself depending on its mission profile (Heller). There will be backup systems and redundant systems in case of any failure in any part of the sensor package (Moseby). Communication for this concept will implement ultra wideband technology for LOS and BLOS communications. These communications can be sent from the ground station or current military satellites.

maximum speed.

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Since the specification does not require that the vehicle actually move on the ground, wheels, legs, tracks, and other methods of ground mobility can be dropped from consideration. A simple solution is to utilize a system that is similar to most retractable landing gear systems used today. A landing strut will be housed within the skin of the vehicle and a push-pull pneumatic cylinder used to extend and retract the strut.

The Ionic Defender is designed with the purpose of maintaining a low radar cross section and near quiet acoustic signature. In order to produce a near quiet acoustic signature, a virtually silent propulsion system is used. This propulsion system is based on Electro-kinetic air transportation technology. This transportation system will be used for both vertical, horizontal and “near earth” flight configurations. This UAGV system is illustrated in Figure 4 of section 5.

The Ionic Defender utilizes ion propulsion for vertical and horizontal flight. Ion propulsion uses high voltage electric plates to ionize the surrounding air. The ionized air is then attracted to another grid and ducted out. The electricity is provided by high capacity fuel cells. This process is completely silent and creates no heat. The ion engines will be used for hover for near ground activities and for VTOL. Also there will be separate ion engines for horizontal propulsion. The lifting body design will reduce the need for the vertical ion engines during horizontal flight.

The power source for this system is also a fuel cell. This solid oxide fuel cell provides up to 25 kilowatts of power and can run on various fuels, such as diesel and JP-8, with the aid of an external reformer. Siemens Westinghouse Power has maintained testing of this fuel cell for over 9,000 hours (National Fuel Cell Research Center).

The flight control and navigation systems are fully autonomous. The flight control and navigation system is based on a top-down process with input from several sensors and cameras (McLean). The vehicle is able to direct itself depending on its mission profile (Heller). There will be backup systems and redundant systems in case of any failure in any part of the sensor package (Moseby). Communication for this concept will implement ultra wideband technology for LOS and BLOS communications. These communications can be sent from the ground station or current military satellites.

2.4 Concept 3D “Ionic Defender”

The monocoque structure of this concept gives the concept tremendous strength and durability. The monocoque uses an exoskeleton design with a layered composite skin. The skin is layered with carbon fiber, bore fiber, electro-chrome, and radar absorbing material. The fiber structure is the strongest part of the skeleton. The electro-chrome layer absorbs electromagnetic radiation emitted from within the vehicle and outside the vehicle. Lastly the skin is covered with a radar-absorbing layer to lower the radar cross section adding to the vehicles stealth capabilities.

3.0 Selection of Final Concept

Although the Ionic Defender is unconventional, it proves to be the most innovative design that is able to meet most, and exceed many of the requirements set forth by the specifications. Based on its near quiet operation, low power consumption, and stealth-like mobility the Ionic Defender will be capable of completing any mission profile defined by the Army. Tables 1 and 2 show a summary of capabilities pertaining to each of the reviewed concepts and an evaluation matrix based on a risk assessment for each concept based on criterion derived from the specification.

4.0 Issues for Selected Concept

4.1 Development Issues

The technologies involved have to be validated and demonstrated. Logical ways of thinking have to be created to handle survivability and mission objective parameters. A low weight, high output power source is required. This need is beyond the limits of current technology. Although some high output power sources exist, they weigh far too much for use in a compact remote system.

Ionic Propulsion will provide ample power for maneuvering and speed. Additionally it will increase survivability due to the extremely low acoustic signature. However revolutionary, ionic propulsion is an infant technology and would require time, devotion, and effort to make it reliable for use in this or any other system.

Currently no system, beyond handheld phones and satellite phones, provide any means of beyond line of sight communication (BLOS). The concept of BLOS communication would also require technological advancement to ensure accurate and secure communication between the remote units and the control station.

Substantial effort on the modern battlefield is spent toward increasing survivability. All of the key issues here in some way relate to increasing survivability of the unit on the battlefield.

4.2 Phase 3 Plan

Phase 3 will further develop the Ionic Defender concept. Members will concentrate on specific disciplines to refine all subsystems and identify future problems with integration. Key issues include the numerical and experimental verification of the propulsion system and infrastructure. The electrical discipline will be responsible for providing an adequate power source and sensor package based on infant technology. The thought process for AI will be further expounded by evaluating criteria contained in the spec based on survivability, mission profile, and resources. To prove the ion propulsion system concept is within our grasp we intend on making a working prototype of the engine given enough time. We believe that this concept will provide AMCOM with a realistic system to meet all requirements related in the specification.

5.0 Illustrations



Figure 1. Concept 3A "Pawnee"



Figure 2. Concept 3B "Roto-Racer"



Figure 3. Concept 3C "Moth"



Figure 4. Concept 3D "Ionic Defender"

Table 1. Concepts Comparison

Comparison Criteria	Baseline	3A	3B	3C
Overall Specifications	Pawnee	Roto-Racer	Moth	Ionic Defender
Air Configuration	Coaxial Rotor	Coaxial Rotor	Ducted Fan	Ionic Engine
Ground Configuration	Wheels	Wheels	Hover	Hover
Payload Mass, kg (lb)	27.2 (60)	27.2 (60)	27.2 (60)	27.2 (60)
Gross Takeoff Weight, kg (lb)	280 (618)	181 (400)	91 (200)	114 (250)
Energy Source for Air Transport	JP-8	JP-8	JP-8/ Fuel Cell	JP-8/ Fuel Cell
Energy Source for Ground Transport	JP-8	JP-8	JP-8/ Fuel Cell	JP-8/ Fuel Cell
Hovering Power, KW (hp)	25 (33.6)	16.7 (22.4)	67 (90)	6 (8)
Cruise Power, KW, (hp)	49.4 (66.3)	33.2 (44.5)	52 (70)	4 (5.4)
Total Energy for Mission Profile, KJ (BTU)	$7.37 \times 10^{+5}$ ($6.986 \times 10^{+5}$)	$5.766 \times 10^{+5}$ ($5.466 \times 10^{+5}$)	N/A	N/A
Basis of Autonomy	None	AI/VR	AI/VR	AI/VR
Primary BLOS Method	N/A	K BAND	K BAND	K BAND
Primary Structural Material	N/A	Bore Fiber	Bore Fiber	Bore Fiber
Processing	Existing	NAV	NAV	NAV
Propulsion	Existing	Piezo Blades	N/A	Ion Prop.
Power System	Existing	Photo material	N/A	N/A

This table compares the similarities and differences between each system by concept.

Table 2: Concept Evaluation Matrix

	Factor	3A <i>Pawnee</i>	3B <i>Roto-racer</i>	3C <i>Moth</i>	3D <i>Ionic defender</i>
Innovation	5	-	-	+	+
Range: 15 km from launch point	5	+	+	+	+
Cruise Speed of 30 km/hr	4	+	+	+	+
VROC of 250 ft/min	3	-	+	+	+
VTOL Capability	4	+	+	+	+
Payload: 60 lbs	2	+	+	+	+
Operational Altitude of 0 to 500 ft AGL	3	+	+	+	+
Hover to full flight profile	4	+	+	+	+
Autonomous or Semi-autonomous	2	-	+	+	+
Near Quiet Acoustic Signature	5	-	-	-	+
BLOS communications	5	-	+	+	+
Cost/Risk/Schedule	4	+	+	+	-
Potential Reliability (RAM)	4	-	-	+	+
Totals	50	2	22	40	42

This table is the concept evaluation matrix. Its goal is to help GRAD Inc. determine the best concept for further development. The factor column represents the weight of the key challenges and specifications that such a design involves. Five being the most important point and one being the least important. Each of the key concept factors are totaled and compared to the baseline as a reference. The design with the most total points will be chosen for the final concept.

Normalized	100	4	44	80	84
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References

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<http://www.globalte.com/fcprogram-main.htm>. Accessed 2/17/01.

Heller, C. 1998. Design Optimization and Computational Validation of a Terrain Following UAV System. Sir Lawrence Wackett: Australia

McLean,D. 1990. Automatic Flight Control Systems. Prentice Hall: United Kingdom

Moseby, Theresa. Remote Sensors Platforms. Office of Naval Research

National Fuel Cell Research Center. 25KW Solid Oxide Fuel Cell Project Description. 2000.
<http://www.nfcrc.uci.edu/about/projects/index.htm>. Accessed 2/22/01

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National Fuel Cell Research Center. 25KW Solid Oxide Fuel Cell Project Description. 2000. <http://www.ncfrc.uci.edu/about/projects/index.html>. Accessed February 22,2001.
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Word List

IPT _:

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Word	Comments
AGL	Above Ground Level
AI	Artificial Intelligence
AMCOM	United States Army Aviation and Missile Command
ATR	Aided Target Recognition
BLOS	Beyond Line of Sight
BTU	British Thermal Unit
C2	Command and Control
C4I	
CAD	Computer aided design
COM	Communication
CDD	Concept Description Document that details the customer's technical specifications for the UA/UGV
CST	Central Standard Time
Customer	John Fulda and Jim Winkeler
DOD	Department Of Defense
Dry Weight	Weight of vehicle without fuel or payload
EE	Electrical Engineering
EH	English
EM	Engineering Management
EST	Editorial Support Team
ESTACA	Ecole Superieure des Techniques Aeronautiques et de Construction
FCC	Federal Communication Commission
FLOT	Forward Line of Troops
Ft	Feet
GRAD Inc.	Global Research And Development Incorporated
Hp	Horsepower
Hr	Hour
IFF	Identification Friend or Foe
IPT	Integrated Product Team
IRP	Intermediate Rated Power
JCDL	
JAUGS	Joint Architecture for Unmanned Ground Systems
JP-8	Jet Propulsion Fuel 8
km	Kilometer
lbs.	Pounds
LOS	Line Of Sight
MAE	Mechanical and Aerospace Engineering
Monocoque	Structure where skin absorbs most of the force
MKT	Marketing
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
nm	Nautical miles (~2025 yds)
Payload	Item carried by the system having a specified weight
Phase 1	Baseline review, conducted on conventional

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	configuration using current and experimental technology, assess technologies clarify the Concept Description Document
Phase 2	Alternative concepts review, development and evaluation of four prototype designs to meet customer specifications. Select a preferred design.
Phase 3	Final Evaluation, detailed design specifications of selected design concept
RFP	Request for Proposal
RMA	Revolution of Military Affairs
RSTA	Reconnaissance, Surveillance, & Target Acquisition
SOFC	Solid Oxide Fuel Cell
Style Guide	Document that specifies the mechanics of writing documents required for the project
TBD	To be determined (not know at this time)
TF/TA	Terrain following/terrain avoidance
UAH	The University of Alabama in Huntsville
UAV	Unmanned Air Vehicle
UAGV	Unmanned Air/Ground Vehicle
UGV	Unmanned Ground Vehicle
U.S.	United States
VROC	Vertical rate of climb
VTOL	Vertical takeoff and landing

Appendix C - France Travel Team (Sheree)

The following will go to France if our team is selected. The Table also represents the order of preference of team member if the team is not selected by additional slots are available. First member must be willing to present summary of team results. If you are proposing taking a friend or family member, please include.

NAME AS IT APPEARS ON PASSPORT	NATIONALITY	PASSPORT EXPIRATION DATE
Nathan Smith	American	12/2010
Sheree Long	American	2/2011
Jason Back	American	3/2011
Younes Elkacimi	American	4/2011

Four GRAD-INC. team members will be traveling to France. The travel costs to and from our destination will be approximately twenty-one hundred dollars. Since four thousand dollars was donated to the class by the UAH student government association, the extra nineteen hundred dollars will be used for food expenses of the team members.

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Appendix D - Team Member Resumes [required]

Akmal P. Abdulakhatov

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Email akmal_uah@hotmail.com

Permanent Address

Bobir St 14b 55
Tashkent City,
CIS Uzbekistan, 702132
Phone 998 712 60-6853

Key Words

Mechanical Engineering, Aerospace Engineering, Solid Edge CAD, AutoCAD, Programming Languages, Mechanical Workshop

Education

The University of Alabama in Huntsville Huntsville, AL

Bachelor of Science, Mechanical/Aerospace Engineering

Expected graduation date: Summer 2001

- Minor: Math
- GPA: 3.6/4.0
- Relevant Coursework: statics, dynamics, mechanics of materials, fluid dynamics, heat and mass transfer, engineering design, kinematics and dynamics of machines, thermodynamics, electric circuits analysis, engineering economy, nature and properties of materials, engineering graphics solid edge, drafting, materials science, aerodynamics, aerospace propulsion, systems design, aerospace structures, aircraft stability and control, partial differential equations
- Work Sample: http://mortonweb.uah.edu/ipt2001/AbdulakhatovA_work.pdf
- Honors: Honor student, Dean's List, Earned all of college expenses through scholarships.

Technical Skills

- Fluent in English, Russian, and Turkish
- Operating Systems: Windows 98, 2000, NT, and DOS
- Computer Languages: C, Turbo Pascal
- CAD / FEM Systems: AutoCAD, Solid Edge, MathCAD
- Major Software Packages: MS Office

Interests and Activities

Drafting experience on the drafting board, electric and gas welding skills, pyrotechnics, machine workshop working experience (lathing, milling, and welding), building and testing several computer PC systems, home building, farming

IPT _:

Current as of October 29, 2002

Jason M. Back

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(C) (256) 426-0900

Email backj@email.uah.edu

Key Words

Mechanical Engineering, Aerospace Engineering, Space Station, Rocket Design, IPT, VMAP, Microstation

Education

- The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering

Expected graduation date: May 2001

- Relevant Coursework: thermodynamics, mechanics, fluid mechanics, dynamics, basic circuits, design, aerodynamics, aerospace structures, aircraft stability and control, propulsion, experimental techniques of measuring solids, space station engineering, reusable rocket design, integrated product team design
- Work Sample: http://mortonweb.uah.edu/ipt2001/BackJ_work.pdf
- Honors and Affiliations: SGA Student Leadership Award 99-00, Freshman Merit Scholarship, Student Government Association (Legislature and Finance Officer), Sigma Nu Fraternity (Treasurer, Alumni Relations, Secretary)

Technical Skills

- Operating Systems: Windows 95, 98, NT, 2000, and DOS
- Major Software Packages: MS Office 2000 (Word, Excel, Power Point, Access), Bentley Microstation
- Computer software and hardware installation
- CAD Systems: AutoCAD, Solid Edge

Work Experience

- Sep 1998 – Dec 2000 Huntsville, AL Terra GIS
Digital Map Converter
 - Used Bentley Microstation to convert lithographic information into digital map data.
 - Performed quality control checks on Vector Map before sending to the customer.
 - Used Intergraph Software: Geovec, IRASB, and IRASC.
- Aug 1994 – Aug 1997 Valumarket Louisville, KY
 - Stock Clerk
 - Assembled and disassembled store displays.
 - Operated a cash register in checkout lanes.
 - Bagged groceries for customers and retrieved shopping carts.

References

Available on Request

IPT _:

Current as of October 29, 2002

Jean-Emmanuel Bzdrega

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92300 Levallois-Perret, France
E-mail jeb.com@libertysurf.fr

Key Words **Mechanical Engineering, Aeronautical Engineering, Engines, Control Systems, Robotics, CATIA, C Programming, Nastran/Patran, Matlab/Simulink, French, German**

Education

- ESTACA Levallois-Perret, France
Bachelor of Science, Mechanical/Aeronautical Engineering
Expected graduation date: Jun 2002
- Specialization: Aeronautical and control systems
- Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, circuits, design, aerodynamics, aeronautical structures, aircraft stability and control, propulsion
- Work Sample: http://mortonweb.uah.edu/ipt2001/BzdregaJ_work.pdf

Technical Skills

- Operating Systems: Windows 95, 98, NT, Unix, and DOS
- Computer Languages: C; Matlab/Simulink
- CAD / FEM Systems: CATIA, Nastran/Patran, ADAMS
- Major Software Packages: MS Office 2000 (including Access)

Work Experience

- Jul 1999 Snecma Engines
Gennevilliers, France
- Production Engineer
- Fabrication of fans for CFM-56 –5 and –7 engines.
 -
- Jul 1998 – Aug 1998 Brooklands
Museum Weybridge, England
- Maintenance Worker
- Maintenance on planes and cars in a museum
- Jun 1997 Savoye Sport
Berck/Mer, France
Sports Car Mechanic
- Maintenance and optimization of olds sports car engines.

References Available on Request

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Younes Elkacimi

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Key Words **Aerospace Engineering, Mechanical Engineering, AutoCAD, I-DEAS, C, Aerodynamics, Propulsion, French, Arabic, Databases, Research**

Education The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/ Aerospace Engineering
Expected graduation date: Dec 2001

- Minor: Math
- Relevant Coursework: senior design of air-ground robot vehicle, fluid mechanics, materials science, thermodynamics, circuits, aircraft stability and control, system dynamics, dynamics, static, I-DEAS design
- Work Sample: http://mortonweb.uah.edu/ipt2001/ElkacimiY_work.pdf
- Honors and Affiliations: Phi Theta Kappa Honor Society, Outstanding Junior College Scholarship, Engineering Dean's List

Wallace State College Hanceville, AL
Associate of Science, Engineering
Graduation date: Aug 1998

Technical Skills

- Operating Systems: Windows 95, 98, NT
- Computer Languages: C, Q-Basic
- CAD/FEM Systems: I-DEAS, AutoCAD 14
- Major Software Packages: MS Office 97

Work Experience Sep 2000 - Present General Electric Decatur, AL
Co-op Advanced Manufacturing Engineer

- Compile machines part requirements from new equipment suppliers and create expense crib listings.
- Relocate and design work stations.

May 1999 – Apr 2000 Steelcase Inc. Athens, AL

Co-op Manufacturing Engineer

- Calculated surface areas of all parts manufactured in the plant and maintained the database.
- Implemented quality standards of particular products and improved production.
- Performed material and labor costs for different products.

Dec 1998 - Sep 2000 The University of Alabama in Huntsville Huntsville, AL
Tutor, Department of Engineering

- Tutored students in Math and Physics.
- Graded Fluid Mechanics, Dynamics, and Statics papers.

References Available on Request

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Permanent Address

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des Trois Moulins
Rubelles, 77950
Phone (33) 1 60 68 41 64

Key Words	Mechanical & Automotive Engineering, Noise & Vibration, CATIA, Matlab-Simulink, Nastran, ADAMS, I-DEAS		
Education	<ul style="list-style-type: none"> ESTACA 	Levallois-Perret, France	
	Five-year program in Automotive/Noise & Vibration Engineering Expected graduation date: Jun 2002 <ul style="list-style-type: none"> Minor: German Relevant Courses: automotive engineering, manufacturing science, signal processing, modal analysis, vibrations, sensors, noise Work Sample: http://mortonweb.uah.edu/ipt2001/GeffardJ_work.pdf 		
Technical Skills	<ul style="list-style-type: none"> Operating Systems: Windows 95, 98 Computer Languages: Matlab/Simulink CAD / FEM Systems: CATIA, Nastran, Patran, ADAMS, I-DEAS Major Software Packages: MS Office 2000 		
Work Experience	<ul style="list-style-type: none"> Jul 2000 – Aug 2000 	St Quentin, France	Europcar
	Organization Assistant <ul style="list-style-type: none"> Managed cars in Europe. 		
	<ul style="list-style-type: none"> Sep 2000 – Oct 2000 	Paris, France	Citroën
	<ul style="list-style-type: none"> Spare Part's Assistant Assisted department in after-sales duties. 		
	<ul style="list-style-type: none"> Jul 1999 – Aug 1999 	Volkswagen-Audi Germany	Ziegenhain,
	<ul style="list-style-type: none"> Mechanic Performed automotive mechanic duties. 		
References	Available on Request		

IPT _:

Current as of October 29, 2002

Bryan D. Griffin

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Harvest, AL 35749
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Key Words

Mechanical Engineering, Pro/Engineer, AutoCAD

Education

**The University of Alabama in Huntsville
Huntsville, AL**

Bachelor of Science, Mechanical Engineering

Expected graduation date: May 2001

- **GPA.: 3.20/4.00**
- **Relevant Courses:** engineering graphics, thermodynamics, statics, dynamics, design, basic circuits
- **Work Sample:** http://mortonweb.uah.edu/ipt2001/GriffinB_work.pdf
- **Honors and Awards:** Academic Excellence Scholarship for 4.00 HS GPA

Technical Skills

- **Operating Systems:** Windows 95, 98, NT
- **Computer Languages:** FORTRAN, Pascal
- **CAD / FEM Systems:** AutoCAD 12 & 14, Pro/Engineer 2000i, Visio Technical
- **Major Software Packages:** MS Excel

Work

Aug 1999 – Present PEI Electronics Incorporated Huntsville, AL

Experience

Co-op Mechanical Engineer

- **Develop models, assemblies and drawings of new products**
- **Develop hardware in Pro/Engineer.**

**Aug 1998 WTW Engineers and Surveyors
Huntsville, AL**

Surveying Assistant

- **Assisted in re-surveying the boundaries of the William Bankhead National Forest.**

References

Available on Request

IPT _:

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Matthew A. Harris

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Key Words **Mechanical Engineering, AutoCAD, Software and Hardware
Documentation**

Education The University of Alabama in Huntsville
Huntsville, AL

Bachelor of Science, Mechanical Engineering

Expected graduation date: May 2001

- Relevant Coursework: thermodynamics, fluid mechanics, dynamics, aerospace structures, analysis of engineering systems, kinematics, mechanics of materials
- Work Sample: http://mortonweb.uah.edu/ipt2001/HarrisM_work.pdf
- Honors: UAH Dean's List

Technical Skills

- Operating Systems: Windows 95, 98, NT, 2000, and DOS
- Computer Language: C++
- CAD / FEM Systems: Solid Edge, EMS, AutoCAD 14
- Major Software Packages: Adobe Acrobat Writer, MS Office 2000 Professional, Visio Professional 5.0, MS Front Page 2000

Work Apr 1999 – Present ADS Corporation Huntsville, AL
Experience IT Technician

- Company telephone and voice mail systems administration.
- System and network administration.
- PC and network installation.
- PC and network technical support.
- Hardware specifications and department acquisitions.

Avex Electronics Jan 1998 – Dec 1998
Huntsville, AL

PC Technician I

- Worked with internal technical support to solve computer hardware and software problems.
- Maintained all computers and related hardware in manufacturing area.
- Trained operators on new hardware and software.
- Designed custom production labels according to specifications.

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References Available on Request

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Current as of October 29, 2002

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Phone (33) 1 47 08 91 45

Key Words

Mechanical Engineering, Aerospace Engineering, Structures and Materials, CATIA, Nastran, French

Education

- ESTACA Levallois-Perret, France
Five-year program in Mechanics/Aerospace Engineering Expected graduation date: Jun 2002
 - Minor: Structures and Materials
 - Relevant Courses: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, aerodynamics, aerospace structures, aircraft stability and control, propulsion, FEM, Computer Aided Engineering
 - Work Sample: http://mortonweb.uah.edu/ipt2001/HussenetF_work.pdf
 - Affiliation: Responsible for maiden flights at the ESTACA air club
 - Operating Systems: Windows 95, 98, NT, Unix

Technical

- Computer Languages: C++
- CAD / FEM Systems: CATIA, Nastran
- Major Software Packages: MS Office 2000

Skills

Work

Experience

- Jun1999 – Aug 1999 Brooklands Museum London, England
Assistant Project Manager
 - Team leader of an international group of students aiming to restore a Vickers VC-10 in association with British Airways.
- Jun1998 Aerospatiale Toulouse, France
Hand worker
 - Work in the Production Department, for ATR 42 and 72.
- Aug 1994 - 97 Animal Crackers South Laguna, CA
Salesman
 - Salesman in a pet food store.

References

Available on Request

IPT _:

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C-9

James Kodrowski

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Key Words

Leadership, Management, Mechanical Engineering, Aerospace Engineering, Propulsion, Solid Edge, C++, Visual Basic, Spanish, Italian

Education

- The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering
Expected graduation date: May 2001
 - Minor: Math
 - GPA: 3.30/4.0
- Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, design, aerodynamics, aerospace structures, aircraft stability and control, propulsion, engineering economics
- Work Sample: http://mortonweb.uah.edu/ipt2001/KodrowskiJ_work.pdf
- Honors and Affiliations: Student Government Association President, Alpha Tau Omega Fraternity President, UAH Board of Trustees student rep representative, UAH Alumni Association board member, ASME member, student orientation leader, Division I hockey player

Technical Skills

- Operating Systems: Windows 95, 98, NT, and DOS
- Computer Languages: C++, Visual Basic
- CAD Systems: Solid Edge
- Major Software Packages: MS Office 2000

Work Experience

- Oct 1998 – Dec 2000 Propulsion Research Center Huntsville, AL
Research Assistant
 - Assist in the development of experiments in advanced propulsion.
 - Build components and run experiments.
- Sep 1999 – May 2000 The University of Alabama in Huntsville Huntsville, AL
Project Manager, Microlenses in Microgravity Experiment
 - Participate in writing and proposal submission for NASA contracts.
 - Responsible for overseeing, building, testing, and submitting final reports on microgravity experiments.
 - Responsible for overseeing experiment budgets.

References

- Available on Request

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C-10

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Key Words

Mechanical Engineering, Aerospace Engineering, Databases, AutoCAD, C, C++, Visual Basic, Unix

Education

- The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering
Expected graduation date: May 2001
 - GPA: 4.0/4.0
 - Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, design, aerodynamics, aerospace structures, aircraft stability and control, propulsion, heat and mass transfer
 - Work Sample: http://mortonweb.uah.edu/ipt2001/KrishnasamyK_work.pdf
 - Honor: UAH Engineering Dean's List

Technical Skills

- Operating Systems: Windows 95, 98, NT, Unix, and DOS
- Computer Languages: C, C++, Visual Basic
- CAD Systems: AutoCAD 12 & 14
- Major Software Packages: MS Office 2000
- Design and Development:
 - Designed an innovative prototype brake dynamometer for a UAH Racing Car.
 - Designed and developed a thrust propeller for an aircraft design.
 - Designed and developed a column fiber buckling for an aerospace structure field.
 - Designed and worked on a prototype for a multistage rocket.
 - Designed an Unmanned Air/Ground Vehicle with a seven-member team of students from UAH.

Work Experience

- Aug 1999 – Present The University of Alabama in Huntsville
Huntsville, AL
Research Assistant, Department of Electrical and Computer Engineering
 - Troubleshooting computers and network problems.
 - Troubleshooting and debugging software for computer system.
 - Troubleshooting on aerospace propulsion and aerospace structure.

References

Available on Request

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Key Words

Aerospace Engineering, Mechanical Engineering, AutoCAD, I-DEAS, MS Access, MathCAD, MS Project

Education

- The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering
Expected graduation date: May 2001
 - GPA: 3.08/4.0
 - Relevant Coursework: analysis of engineering systems, fundamentals of Space Station engineering, introduction to engineering design, aerospace structures, aircraft stability and control, methods of partial differential equations, aerodynamics, aerospace propulsion
 - Work Sample: http://mortonweb.uah.edu/ipt2001/LongA_work.pdf
 - Honors and Affiliations: Honor Scholars List, American Institute of Aeronautics and Astronautics (2000-2001 student chapter treasurer), American Helicopter Society
- John C. Calhoun Community College Decatur, AL
Associate of Applied Science, Design Drafting Technology
Graduation date: May 1997
 - GPA: 3.4/4.0
 - Relevant Coursework: AutoCAD design, electronic design, strength of materials technology, architectural design, mechanical design, AutoCAD R12, AutoCAD R13
 - Honors and Affiliations: graduated cum laude, Phi Theta Kappa Honor Society, Deans list

Technical

- Operating Systems: Windows 95, 98
- Computer Language: FORTRAN

Skills

- CAD Systems: AutoCAD R11, R12, R13, R14, 2000i, I-DEAS
- Major Software Packages: MS Office (including Access), MathCAD, MS Project

Work Experience

- Jan 1998 - Jan 2001 Saint-Gobain
Industrial Ceramics Huntsville, AL
Co-op Mechanical Engineer
 - Performed flow and duct sizing calculations for dust collection systems.
 - Developed process flow diagrams, equipment layout drawings, and structural steel fabrication drawings.
 - Designed and tested air nozzles for quenching.
 - Verified field placement of equipment.
 - Managed various capital projects from conception through completion.

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Key Words

Mechanical Engineering, Aerospace Engineering, Propulsion, Research, Solid Edge, FORTRAN, German, LabView, Ladder Logic, I-DEAS

Education

- The University of Alabama in Huntsville Huntsville, AL
Bachelor of Science, Mechanical/Aerospace Engineering
Expected graduation date: May 2001
 - Minor: Mathematics
 - GPA: 3.01/4.0
- Relevant Coursework: thermodynamics, materials science, fluid mechanics, dynamics, basic circuits, design, aerodynamics, aerospace structures, aircraft stability and control, propulsion
- Work Sample: http://mortonweb.uah.edu/ipt2001/SmithN_work.pdf
- Honors and Affiliations: American Institute for Astronautics and Aeronautics (AIAA), first place at AIAA Southeastern Regional Student Conference April 2000, Lancers, UAH Engineering Dean's List, Order of Omega Honor Society, American Helicopter Society, Alpha Tau Omega Fraternity

Technical Skills

- Operating Systems: Windows 95, 98, NT, Unix, and DOS
- Computer Languages: FORTRAN, MathCad, Ladder Logic
- CAD / FEM Systems: Solid Edge, I-DEAS
- Major Software Packages: MS Office 2000 (including Access), MathCAD, LabView

Work Experience

Sep 1998 – Present Propulsion Research Center Huntsville, AL
Research Assistant

Experience

- Design and build propulsion test facility for research of rocket engines.
- Research several different rocket systems including liquid-chemical, solid, and hybrid rocket engines.

Patents and Publications

- May 1996 – Present J.A.N. Company Scottsboro, AL
Owner/Operator
 - Residential design, remodeling, and construction.
 - Cost estimation, public relations, management.
 - "Facility Design and Testing of Micro Hybrid Rocket Engines" AIAA Paper #2001-0005.
 - US Design Patent #D404,501, "Design of PVC Fence Panel."

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Appendix E – Sample Calculations

E1 – Propulsion and Power Calculations (Jason Back)

Ionic Defender Propulsion Power Calculations

These equations were adapted from the rotorcraft code used in the baseline calculations. This assumes that the ducts from the vehicle act as a solid disc area such as in a rotorcraft. My calculations at the bottom used fluids equations the difference between the power to hover is only about 8 hp. Is it possible to use these equations and assumptions as I did?

Known Values:

Vehicle Mass

$$M_{uav} := 300 \text{ lb}$$

$$M_{uav} = 136.078 \text{ kg}$$

$$W_g := M_{uav} \cdot g$$

$$W_g = 300 \text{ lbf}$$

$$T := 95^\circ\text{F}$$

$$\text{Altitude} := 4000 \text{ ft}$$

Total Duct Area (3 ducts)

$$\text{Area} := 24.038 \text{ ft}^2$$

$$\text{Disc_Load} := 12.48 \frac{\text{lb}}{\text{ft}^2}$$

$$\text{Disc_Load} = 60.933 \frac{\text{kg}}{\text{m}^2}$$

$$\frac{300}{24.038} = 12.48$$

$$A := \frac{M_{uav}}{\text{Disc_Load}}$$

$$A = 2.233 \text{ m}^2$$

Duct(s) Downwash velocity (v)

Density

$$\rho_{hmax} := 1.095 \frac{\text{kg}}{\text{m}^3}$$

$$\rho_{hmax} = 2.125 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3}$$

Velocity

$$V_{hmax} := \sqrt{\frac{W_g}{2 \cdot \rho_{hmax} \cdot A}} \quad V_{hmax} = 54.194 \frac{\text{ft}}{\text{s}}$$

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(B) Power to climb

$$\text{VROC} := 250 \frac{\text{ft}}{\text{min}}$$

$$\text{VROC} = 1.27 \frac{\text{m}}{\text{s}}$$

$$P_{2\text{climb}} := \frac{W_g \cdot (V_{\text{hmax}} + \text{VROC})}{2} + W_g \cdot (V_{\text{hmax}} + \text{VROC})$$

$$P_{2\text{climb}} = 47.74 \text{ hp}$$

$$P_{2\text{climb}} = 3.561 \times 10^4 \text{ W}$$

(C) Power to Hover

$$P_{2\text{hover}} := \frac{W_g \cdot V_{\text{hmax}}}{2} + W_g \cdot V_{\text{hmax}}$$

$$P_{2\text{hover}} = 44.34 \text{ hp}$$

$$P_{2\text{hover}} = 3.306 \times 10^4 \text{ W}$$

My Calculations

Using these equations:

$$\dot{m} := \rho_{\text{hmax}} \cdot \text{Area} \cdot v$$

$$E := \frac{1}{2} \cdot \dot{m} \cdot v^2$$

$$F := \rho_{\text{hmax}} \cdot \text{Area} \cdot v^2$$

$$P := F \cdot v$$

Velocity out of the ducts

Mass Flow

$$v := \sqrt{\left(\frac{W_g}{2 \rho_{\text{hmax}} \cdot \text{Area}} \right)}$$

$$\dot{m} := \rho_{\text{hmax}} \cdot \text{Area} \cdot v$$

$$v = 54.194 \frac{\text{ft}}{\text{s}} \quad v = 36.951 \frac{\text{mi}}{\text{hr}}$$

$$\dot{m} = 40.393 \frac{\text{kg}}{\text{s}}$$

Power Required to climb

$$\text{VROC} := 250 \frac{\text{ft}}{\text{min}}$$

$$P := W_g \cdot (v + \text{VROC})$$

$$P = 31.83 \text{ hp}$$

$$P = 2.374 \times 10^4 \text{ W}$$

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E2-Aerodynamics Calculations (Akmal and Kanna)

Drag analysis for front engine

max. thickness cord length

$$t := 0.75\text{in} \quad c := 3\text{in} \quad d := \frac{t}{c} \quad d = 0.25 \quad \rho := 1.2 \frac{\text{kg}}{\text{m}^3} \quad V := 54.2 \frac{\text{ft}}{\text{s}}$$

NACA 0025 airfoil from reference chord

$$Cd_0 := 0.0143 \quad Cd := Cd_0 \quad Cd = 0.014$$

Since the airfoil is symmetric with zero camber the $Cl=0$, therefore
 $Cd=Cd_0=\text{const}$

$$\text{Drag} := Cd \cdot \frac{1}{2} \rho \cdot V^2 \cdot S \quad \text{drag per electrostatic grid panel}$$

There are 9 panels in longitudinal direction of the length 36" with cord 3" NACA 0025
 and 6 panel in lateral direction of the length 54" NACA 0025

one longitudinal panel area S_{long}

$$\text{long_length} := 36\text{in}$$

$$S_{\text{long}} := c \cdot \text{long_length} \quad S_{\text{long}} = 0.75\text{ft}^2$$

lateral panel area S_{lat}

$$\text{lat_length} := 54\text{in} \quad S_{\text{lat}} := c \cdot \text{lat_length} \quad S_{\text{lat}} = 1.125\text{ft}^2$$

$$S_{\text{total}} := 6 \cdot S_{\text{lat}} + 9 \cdot S_{\text{long}}$$

$$S_{\text{total}} = 13.5\text{ft}^2$$

Drag due to flow through the front engine

$$\text{Total_Drag} := Cd \cdot \frac{1}{2} \rho \cdot V^2 \cdot S_{\text{total}}$$

$$\text{Total_Drag} = 2.937\text{N}$$

SI

$$\text{Total_Drag} = 0.66\text{lbf}$$

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E3-Weight Calculations (James Kodrowski)

Structure₂₀₁₀ := 75lbf

Payload := 60lbf

Fuel₂₀₁₀ := 46.4lbf

Sensorscomm := 5lbf

Engine₂₀₁₀ := 30lbf

Fuelcell₂₀₁₀ := 54.6lbf

$VCL_{total} := \text{Structure}_{2010} + \text{Fuel}_{2010} + \text{Engine}_{2010} + \text{Sensorscomm} + \text{Payload} + \text{Fuelcell}_{2010}$

$VCL_{total} = 271\text{lbf}$

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E4-Power Generation (Sheree Long and Younes Elkacimi)

$$FC_{2000} := .00285 \frac{\text{kg}}{\text{W}} \cdot 33000 \text{W} \cdot \text{g}$$

$$FC_{2004} := 0.002 \frac{\text{kg}}{\text{W}} \cdot 33000 \text{W} \cdot \text{g}$$

$$FC_{2000} = 207.345 \text{bf}$$

$$FC_{2004} = 145.503 \text{bf}$$

$$\text{Decrease}_{2004} := \frac{(FC_{2000} - FC_{2004})}{FC_{2000}}$$

$$\text{Decrease}_{2004} = 0.298$$

Assuming that the power increases and weight decreases by 30% every four years (As shown in "Cost Analysis of Fuel Cell-System for Transportation: Arthur D. Little.)

$$FC_{2008} := FC_{2004} - FC_{2004} \cdot \text{Decrease}_{2004}$$

$$FC_{2008} = 102.109 \text{bf}$$

$$FC_{2010} := FC_{2008} - FC_{2008} \cdot .3$$

$$FC_{2010} = 71.476 \text{bf}$$

$$\text{Consumption}_{2001} := 0.208 \frac{\text{liter}}{\text{min}}$$

$$\rho_{\text{gasoline}} := 800 \frac{\text{kg}}{\text{m}^3}$$

$$\text{Time} := 180 \text{min}$$

$$\text{Consumption}_{2010} := \text{Consumption}_{2001} - (\text{Consumption}_{2001} \cdot .3)$$

$$\text{Consumption}_{2010} = 0.146 \frac{\text{liter}}{\text{min}}$$

$$\text{Fuelweight} := \rho_{\text{gasoline}} \cdot \text{Time} \cdot \text{Consumption}_{2010} \cdot \text{g}$$

Resource: "Compact Fuel Processors for Automotive Fuel Cells"

$$\text{Fuelweight} = 46.223 \text{bf}$$

$$\text{Fuelamount} := \left(\frac{\text{Fuelweight}}{\text{g}} \right) \cdot \frac{1}{\rho_{\text{gasoline}}}$$

$$\text{Fuelamount} = 6.923 \text{gal}$$

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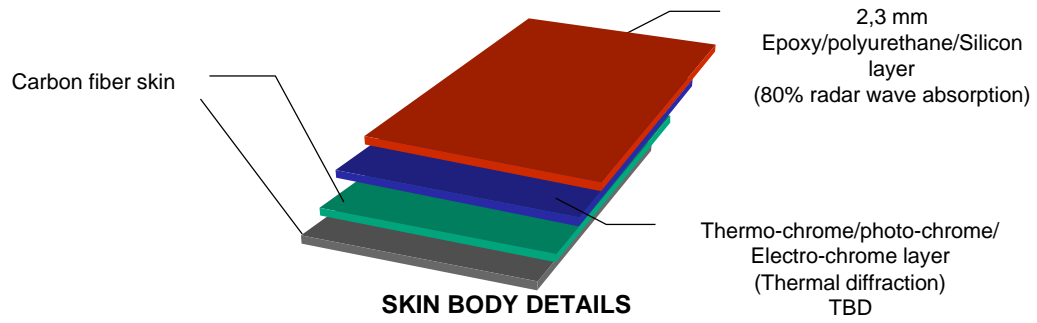
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E5-Top/Down Thinking Process Diagrams

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E7- Materials Diagrams and Calculations



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